NATIONAL SCIENCE FOUNDATION
NATIONAL ACADEMY OF SCIENCES

HEARINGS

BEFORE THE

SUBCOMMITTEE OF THE
COMMITTEE ON APPROPRIATIONS
HOUSE OF REPRESENTATIVES

EIGHTY-SIXTH CONGRESS

FIRST SESSION

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REPORT ON THE INTERNATIONAL GEOPHYSICAL YEAR

(February 1959)

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NATIONAL SCIENCE FOUNDATION—NATIONAL ACADEMY OF SCIENCES

WEDNESDAY, FEBRUARY 18, 1959.

THE INTERNATIONAL GEOPHYSICAL YEAR

WITNESSES

DR. ALAN T. WATERMAN, DIRECTOR, NATIONAL SCIENCE FOUNDATION

DR. DETLEV W. BRONK, CHAIRMAN, NATIONAL SCIENCE BOARD; PRESIDENT, NATIONAL ACADEMY OF SCIENCES

DR. J. WALLACE JOYCE, NATIONAL SCIENCE FOUNDATION

DR. JOSEPH KAPLAN, CHAIRMAN, NAS, U.S. NATIONAL COMMITTEE FOR THE INTERNATIONAL GEOPHYSICAL YEAR (PROFESSOR OF PHYSICS, UNIVERSITY OF CALIFORNIA AT LOS ANGELES)

DR. GEORGE P. WOOLLARD, MEMBER, NAS, USNC–IGY TECHNICAL PANEL ON SEISMOLOGY AND GRAVITY; MEMBER, NAS SPACE SCIENCE BOARD (PROFESSOR, GEOLOGY, UNIVERSITY OF WISCONSIN)

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DR. FRANCIS W. REICHELDERFER, MEMBER, NAS, U.S. NATIONAL COMMITTEE FOR THE INTERNATIONAL GEOPHYSICAL YEAR (CHIEF, U.S. WEATHER BUREAU)

DR. LAURENCE M. GOULD, MEMBER, NAS, U.S. NATIONAL COMMITTEE FOR THE INTERNATIONAL GEOPHYSICAL YEAR; CHAIRMAN, USNC–IGY ANTARCTIC COMMITTEE; CHAIRMAN, NAS COMMITTEE ON POLAR RESEARCH (PRESIDENT, CARLETON COLLEGE)

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R. C. PEAVEY, EXECUTIVE SECRETARY, NAS COMMITTEE ON POLAR RESEARCH; SECRETARY, NAS SPACE SCIENCE BOARD (NATIONAL ACADEMY OF SCIENCES)

Mr. THOMAS. Gentlemen, will the committee please come to order! This morning we have a roomful of distinguished and learned scientists with us. We are honored to have each of you with us.

The purpose of the meeting is to take a look at the International Geophysical Year, as the members have been able to take a closer look at its activities.

In this regard, we would certainly like to have Dr. Waterman, the Director of National Science Foundation, take the lead and then he, I am sure, will want to turn the show over to our able and distinguished friend, Dr. Joseph Kaplan, Chairman, NAS, U.S. National Committee for the IGY. Of course, no meeting would be complete without our lovable and able friend, Dr. Bronk, President of the National Academy of Sciences.

Dr. Waterman, would you lead off and direct the signals?

STATEMENT OF DR. ALAN T. WATERMAN

Dr. WATERMAN. Thank you, sir.

Mr. Chairman, gentlemen, it is a pleasure again to meet with this committee and discuss some of the results of the International Geophysical Year program. The scientific community appreciates the committee's continuing interest in the progress of the IGY and its accomplishments.

A great deal has been said about the immense proportions of the IGY as a cooperative enterprise involving 66 countries. This aspect of the program and its importance cannot be overemphasized. Already scientific results of great importance have been achieved and as the work of data analysis and further research goes on undoubtedly

there will be progress, at least as great or greater, throughout the field of geophysics as a result of the IGY program.

Within the United States alone the teamwork that has made possible this country's contribution to the worldwide IGY effort has been impressive in itself. The success of the IGY, as reflected in part by the results that will be reported here today, could only have been achieved through the foresight of your committee and the Congress in supporting the program and contributing generously to it, through the talents and efforts of scientists in every section throughout our land, and through the U.S. National Committee for the IGY, which in its key role of planning and following through the U.S. IGY program, deserves the highest tribute.

The IGY Committee of the National Academy of Sciences-National Research Council has assembled witnesses, most of whom have appeared here before, to report to you today on various portions of the IGY program. Their last report to you—in June of last year, you will recall—was a review of the first 11 months of the program. Because the formal period for the IGY closed on December 31, 1958, the report today will cover the preliminary findings of the entire 18-month period.

It is my pleasure to turn the meeting over to Dr. Bronk, President of the National Academy of Sciences and Dr. Joseph Kaplan, who as you know, is the Chairman of the U.S. National Committee for the IGY.

Mr. THOMAS. That is a fine statement.

STATEMENT OF DR. DETLEV W. BRONK

Dr. BRONK. Mr. Chairman, my role is a very simple one, but one in which I have had a great deal of pleasure and satisfaction. That was to appoint the committee which has carried out the planning for the IGY.

Because of their natural modesty, I may be privileged to say a few things that they might not wish to say, and would not say. One is that they have given great service with selfless devotion to a tremendous undertaking, which has not only been of tremendous significance, because of the information which has come from it, but because it has shown that not only scientists representing various disciplines in this country can work together, but that the scientists of all countries can work together in a common undertaking.

I think that it is fair to say that the international significance of the program, as its name bears out, has been of greater significance than even the very important discoveries which have been made.

At a time when we are torn asunder by ideological differences and by selfish national attacks upon the freedom we stand for, it is heartening to find that there are some things that people can do together with common amity.

Mr. Yates was discussing the role of the social sciences just a moment ago with regard to finding out how peoples can avoid war. I am not a social scientist and I do not know the answer to that, but I do know that this program has demonstrated that people can work together for a common end.

This, perhaps, is a very important contribution to the social sciences in showing how people can work together.

I think it is also significant that this program has emphasized the importance of learning more about the world in which we live; the environment which determines our behavior, which determines what we can do and how we must adjust to it, is, I think, going to be of ever greater importance because of the great technological developments which make it possible for people to move rapidly across the surface of the earth and into outer space and down into the depths of the sea. And so this, I would say, is a second great contribution to the furtherance of human welfare.

I hope that whatever is done in support of science by the Federal Government in the future, we will bear in mind that the IGY program has demonstrated that people can work together and in working together for a common objective can contribute greatly to our material welfare and to extending the bounds of our imagination and our intellectual horizon.

The fact that the papers of our country, the newspapers of our country, have given such a tremendous amount of space to the achievements of this program I think is evidence of the fact that they recognize that the imagination of the peoples of our country, the peoples of the world, have been captured by this great adventure.

This is one of the really satisfying things of this undertaking, and so, Mr. Chairman, I would echo Dr. Waterman's appreciation of the fine support that you and your colleagues have given to this program, the enthusiasm you have given us in heartening us, and the material funds you have made possible for us to carry forward our work.

I would then turn the meeting over to the Chairman of the National Committee of the National Academy of Sciences, Dr. Kaplan, who, as you well know, is not only a good expositor, but a person who has an understanding of what people like to hear about.

Mr. THOMAS. That is a nice statement. We agree with everything you say, including Dr. Kaplan.

Dr. KAPLAN. Thank you very much.

STATEMENT OF DR. JOSEPH KAPLAN

Dr. KAPLAN. Mr. Chairman and gentlemen, first I would like to read a telegram from Dr. Gould, that he sent to me. I think you have one.

Mr. THOMAS. Yes.

I understand he is ill and unable to be present. You have a telegram and the committee has one. Let's put them both in the record and certainly convey to the doctor our good wishes for a speedy recovery.

Dr. KAPLAN. This is the telegram to Mr. Thomas:

NORTHFIELD, MINN., *February 17, 1959.*

ALBERT THOMAS,
House Office Building, Washington, D.C.:

Deeply regret the indisposition which keeps me from your hearing on International Geophysical Year and post-International Geophysical Year plans I have always appreciated your understanding of the importance of the International Geophysical Year and especially your help in our Antarctic program. I cannot emphasize too strongly the importance of expanding our present post-International Geophysical Year program. The closing of Little America is a major disservice to science. It is unfortunate for our prestige as well as for science that we have relinquished our scientific leadership in Antartica to another nation.

LAURENCE M. GOULD.

Dr. KAPLAN. The telegram to me reads:

NORTHFIELD, MINN., *February 17, 1959.*

DR. JOSEPH KAPLAN,
National Academy of Sciences,
2101 Constitution Ave., Washington, D.C.:

Terribly sorry not to join you and other colleagues in our International Geophysical Year report to Mr. Thomas and his colleagues who have from the beginning manifested such deep interest in the whole project. Please express my deep personal regards and regrets to Mr. Thomas. I am scheduled to be at the Mayo Clinic on the 18th.

LARRY GOULD.

Mr. THOMAS. Those are thoughtful telegrams and again may I repeat for all of us, the committee and his fellow scientists, too, we wish him a speedy recovery and hope when he gets to the clinic they give him a new and clean bill of health.

Dr. KAPLAN. Thank you very much.

I have a prepared statement I would like to offer for the record.

(The statement referred to follows:)

I am honored and gratified to have this opportunity to appear before you again, and to be here with you today, with my distinguished colleagues, in order to review the IGY.

Let me say at the outset that this program is not one which I, or those of us within our IGY group, view with a proprietary air. It has been clearly too large a venture to be so misinterpreted. It has been a venture in which scores of institutions and tens of thousands of Americans have participated actively and in which millions of our people have shared. It has been a venture in which you yourselves have participated long and vigorously. I should like to stress this. I should like not only all scientists but all of the people of our Nation to know that had it not been for the members of this committee, our IGY effort would have been a minor one instead of the great scientific success that it has been.

Had it not been for your imagination and foresight, our IGY plans would have remained nothing but plans, for it was this committee which sensed the opportunity and challenge of the IGY. And it was this committee which supported and made possible the IGY.

Here I am speaking of the scientific aspects of the IGY broadly, but the IGY has had many implications aside from the specific projects and programs, one by one, in field after field, which comprised our effort. I am thinking, for example, of the meaning of the IGY to the leadership of this Nation among nations. I am thinking of the achievement of the IGY as a remarkable venture in international cooperation, a subject upon which the chairman of this committee commented during the last IGY hearing of this committee. I am thinking too of the meaning of our effort nationally—for example, the wisdom of this committee in supporting vigorously our satellite program. I am convinced that this Nation would be several years behind where it now is, had not your committee supported the IGY satellite effort.

For such reasons, then, I feel it incumbent upon me to express, vigorously and warmly, the gratitude and appreciation of the Academy's International Geophysical Year Committee and of all the many scientists throughout the Nation who have contributed to this endeavor.

We appreciate deeply the encouragement of this committee during those early days when we first appeared before you with our hopes and plans. We appreciate deeply the support granted by this committee year after year. We are pleased with the interest of this committee in the results and accomplishments of our IGY investigations. As Dr. Merle A. Tuve expressed it so eloquently last year: We have a feeling of great humility in sharing with you, and through you with all our fellow citizens, the distinct progress that has been made in a better understanding of our physical environment—the earth beneath us, the air and water about us, and the universe around us.

I. A Summary

We are assembled here today to review the IGY, to say what now can be said about its results, to review the meanings and implications, and to look ahead on the basis of these experiences to trends, interests, problems, and challenges that lie before us. Here let me make some general observations about the IGY.

Planning and operations

First, I should like to say a few words about the planning, briefly this: The international planning was marked by objectivity and harmony, achieved through a series of general assemblies of scientists themselves from all parts of the world. The national planning was also characterized by these qualities, engaging the freely contributed efforts, year after year, of about 200 leaders in the various fields of geophysics, from all parts of the Nation, assembled by the National Academy of Sciences under the leadership of its president, Dr. Detlev W. Bronk.

Second, let me sketch out the operational aspects of the program. After several years of planning, the IGY began its formal observational and experimental phase on July 1, 1957. Sixty-six participating committees, representing 66 nations, conducted their studies in concert. Some 20,000 to 40,000 scientists, aided by about an equal number of volunteer observers, manned about 4,000 principal stations and about an equal number of secondary stations and sites, reaching from pole to pole. These operational and observational responsibilities were fully discharged during the 18-month venture which ended on December 31, 1958. Moreover, much of this effort still continues, not only because this year (called IGC–59 for International Geophysical Cooperation, 1959) represents a continuation along the lines of IGY, but because the value of such work is obvious.

Third, let me refer in passing to the results. These will be discussed specifically by my colleagues. I shall only make a few general observations:

(1) The IGY has produced a host of unexpected, significant discoveries. Perhaps the most succinct summary is that prepared by the Committee's Executive Director on behalf of our IGY community. His two-part article appeared in two successive issues, at the end of the IGY, in the journal Science, which is the weekly publication of the American Association for the Advancement of Science. At the chairman's wish, I should like to propose that it be included as an appendix to my remarks, for I believe it is a most useful summary.

(2) The IGY achieved its primary goal: The acquisition of a vast body of data in field after field, necessarily taken simultaneously in order to give man not only a planetary view of his environment, but the interrelationships among the various aspects of that environment. These data are still flowing into the three IGY world data centers I discussed last year. The status of this flow may be summarized as follows:

IGY data flow

The current status of the flow of data to world data center A and the interchange of data between center A and the other world data centers is set forth for each subcenter of data center A. The situation differs widely among the centers largely in accordance with the time schedules set forth in the GSAGI guide. The flow of data most nearly approximates the CSAGI schedules in those disciplines in which there was some history of organized international exchange.

To date, world data center A has received data from 62 of the 66 nations participating in IGY. The larger nations, whose programs are extensive, are all included in the group transmitting data. These nations are: Argentina, Australia, Austria, Belgium, Bolivia, Brazil, Bulgaria, Burma, Canada, Ceylon, Chile, China (Taipei), Colombia, Cuba, Czechoslovakia, Denmark, Dominican Republic, East Africa, Ecuador, Egypt, Finland, France, German Democratic Republic, German Federal Republic, Ghana, Greece, Guatemala, Hungary, Iceland, India, Indonesia, Iran, Ireland, Israel, Italy, Japan, Malaya, Mexico, Mongolia, Morocco, Netherlands, New Zealand, Norway, Pakistan, Panama, Peru, Philippines, Poland, Portugal, Rhodesia and Nyasaland, Rumania, Spain, Sweden, Switzerland, Union of South Africa, U.S.S.R., United Kingdom, United States, Uruguay, Venezuela, Vietnam Democratic Republic, and Yugoslavia. Data from three of the remaining four nations are known to have been received by world data centers B and C and will presumably be transmitted to center A in the near future.

The current status of each subcenter of world data center A is outlined below.

Airglow and ionospheric physics.—Central Radio Propagation Laboratory, National Bureau of Standards, Boulder, Colo. During the last 6 months the

volume of incoming data and ionograms increased tremendously. This data center remained fully current in the processing of ionogram film (about 1,100,000 feet or 200 miles), data tabulations, f-plots, and so forth, for transmittal to and exchange with other data centers. Data have been received in quantity from each of the other three data centers.

Visiting scientists have made use of the offices in this center for periods from 1 day to 2 weeks while working with data and ionograms in the data center files. Most of them found the availability of the pre-IGY ionospheric data files to be extremely valuable. Twenty-one individuals, laboratories, or other organizations purchased copies of material on file at the data center during a 6-month period. These purchases ranged from a few data sheets or ionograms to many thousands of feet of ionogram film and copies of hundreds of sheets of data. Two issues of a cumulative catalog of IGY data were prepared in 1958 and mailed to an extensive mailing list.

Aurora (instrumental observations).—Geophysical Institute, University of Alaska, College, Alaska. All-sky camera film has been received from all U.S. stations except those in the Antarctic and the arctic drifting station B, from eight Canadian stations and four stations in the U.S.S.R. Additional data (spectroscopic, photometric, cosmic noise absorption, radar echo, and so forth) have been received from 20 U.S. and 7 U.S.S.R. stations. Copying of film for distribution to the other data centers is proceeding on a routine basis.

Aurora (visual observations).—Rockefeller Hall, Cornell University, Ithaca, N.Y. Data have been received direct from Argentina, Cuba, Canada, Mexico, Hungary, Japan, New Zealand, Rumania, and the United States. Data from Canada and New Zealand were in the form of punched cards: 111,000 from Canada, 2,800 from New Zealand. U.S. observations have totaled 30,000 positive, 120,000 negative from volunteers, 32,000 from the Weather Bureau (plus 100,000 6-hour reports), and 18,000 from antarctic stations. Preliminary hourly maps have been prepared by the center through October 1958, quarter-hourly maps through December 1957.

Cosmic rays.—School of Physics, University of Minnesota, Minneapolis, Minn. Data have been received from 27 of the 37 nations participating in the cosmic ray program. Both the Antarctic stations at Wilkes (United States) and Mirny (U.S.S.R.) number among the stations which have submitted data to center A. In the past 6 months, 359 sheets of data have been reproduced (at cost) at the request of various investigators.

Geomagnetism, gravity, and seismology.—U.S. Coast and Geodetic Survey, Geophysics Division, Washington, D.C. Geomagnetic data have been received from 124 of 233 stations in 31 of the 49 nations participating in the geomagnetic program; gravimetric data from 15 of 75 stations in 6 of the 21 nations, and seismic data from 225 of 392 stations in 33 of 53 nations. The reproduction of data as required for other data centers is current. Copies of magnetograms as recent as September 1958 for some of the U.S. observatories have been dispatched. Gravity records require laborious mathematical computations to render the data into a form suitable for submission to the data centers, hence the flow of these data has been delayed. Requests for data from this center are received at the rate of one or two per week.

Glaciology.—American Geographical Society, Broadway at 156th Street, New York, N.Y. A total of 38 reports have been received to date from glaciological projects conducted in Australia, Canada, the United Kingdom, United States, and U.S.S.R. In addition, the final data reports for the first winter at Ellsworth and pole stations have recently been completed and submitted to the data center. Reports for other antarctic stations are expected shortly. This center issued the first number of a glaciological report series in June 1958, incorporating all reports submitted to the center at that time. A second report in this series is contemplated for the near future.

Longitude and latitude.—United States Naval Observatory, Washington, D.C. As part of the U.S. Naval Observatory's moon position program, there were in operation during IGY 21 moon position cameras in observatories of 15 nations around the world. Precise measurements of plates from these cameras are made at one of four measurement centers and are sent to the U.S. Naval Observatory for computation. One of the four measuring engines is at the U.S. Naval Observatory. Although the moon position program was late in starting, this measurement center has received from 6 stations a total of 1,580 plates, representing 368 observing nights. Of this number of plates, 469 have been measured.

Meteorology and nuclear radiation.—National Weather Records Center, U.S. Weather Bureau, Asheville, N.C. The agreements for submission of data in

meteorology differ from other disciplines in that all data are sent to center C, either direct or via centers A and B. All IGY meteorological data will be reproduced on microcards and sent to centers A and B in this form. The data in center A at present are limited largely to data from stations in the North American hemisphere. There is, in addition, an exchange with world data center B of data for stations in the U.S.S.R. and United States. The shipment of data to world data center C is essentially complete through June 1958 (for certain stations through December 1958). The exchange with world data center B lags behind this dispatch to world data center C by about 1 month.

The CSAGI agreements for exchange of data in nuclear radiation were not made final until after the beginning of IGY. Data in nuclear radiation are now held by world data center A for 66 stations in 15 nations.

Oceanography.—Department of Oceanography and Meteorology, Agricultural & Mechanical College of Texas, College Station, Tex. Data from the sea level program have been received from 17 nations. In many cases, data for the first 12 months of IGY are complete. Cruise data have been received from 13 nations. This exchange of data between centers A and B in oceanography is quite active.

Rockets and satellites.—National Academy of Sciences, Washington, D.C. The CSAGI agreements for the disciplines of rockets and satellites were put forth in April 1958 and were further revised at the Fifth CSAGI Assembly in Moscow in August 1958. At present, data have been received from Argentina, Canada, Denmark, France, Germany, Japan, South Africa, the United Kingdom, United States, and U.S.S.R. For the purpose of rapid dissemination of results in the field, a series of reports was initiated in March 1958. To date, Nos. 1 through 6 of the world data center A "Satellite Report Series" and No. 1 of the "Rocket Report Series" have been issued.

Solar activity.—High Altitude Observatory, Boulder, Colo. Data flow very rapidly in this discipline. Appropriate data are received by world data center A within a few hours for some observations, a few days or weeks for others. This world data center A expects to have completed certain aspects of its operation for IGY by the end of February. (World data center A has primary responsibility for two of the subdivisions of this discipline.) In a series of reports now numbering six, this center has issued intermediate "Reports of Surges and Active Prominence Regions" for the first 15 months of IGY. In addition, issue No. 4 reported "Observations of the Solar Electron Corona" for September 1958–January 1959.

II. The Future

The impact of the International Geophysical Year in the geophysical sciences has been remarkable. In my opinion the International Geophysical Year has ushered in a new era in geophysics. Actually the time was ripe for the International Geophysical Year. In many fields decades and in some centuries of empirical observations lay behind man. In this century, particularly during the last quarter century, great advances in electronic instrumentation made possible accurate measurements. Special tools like rockets and satellites vastly extended the range and scope of possible experiments. The advent of electronic computers and similar automatic data processing devices made possible man's coping with the monumental bodies of data that characterize some of the fields of geophysics—weather and ionospheric physics, for example. Thus it is that the IGY was successful and thus it is that we are at the threshold of major new advances in field after field.

It is no wonder, then, that scientists everywhere recognized the need for continuing certain studies. You will hear about these from my colleagues today, and I shall only note here those areas which call for extension as well as continuity: Oceanography, the Antarctic, solar patrol, and the related warning services and, finally space science. In these areas special international committees or bodies have been established with counterpart committees set up in the United States by Dr. Detlev W. Bronk, President of the National Academy of Sciences.

What I should like to dwell upon for a few minutes is the special program for 1959 called IGC–59. This abbreviation stands for the term International Geophysical Cooperation, 1959, and I should like to report on its inception and status as well as upon the recommendations of our Academy Committee.

International developments leading to the formulation of IGC–59.—Shortly before the Fifth General Assembly of the Comité Special de l'Annee Geophysique International (CSAGI) of the International Council of Scientific Unions (ICSU), July 29–August 9, 1958, Moscow, U.S.S.R., the Soviet IGY

Participating Committee circularized the various IGY participating committees. The Soviet Committee pointed out that the IGY was a greater success than could have been imagined and that this success and the importance of the IGY programs seemed to dictate the extension of the IGY for another year. Committees were asked to send delegates to the Fifth Assembly prepared to take up this policy matter.

Prior to departing for the Fifth General Assembly, the leaders of the U.S. delegation informed representatives of the U.S. Government of the U.S.S.R. proposal and discussed with them U.S. policy on extension of IGY.

During the discussions at the Fifth Assembly, many compelling reasons were advanced for continued geophysical cooperation during 1959 including: (i) The fact that many IGY programs and projects got started late in 1957; (ii) observations of large scale geophysical phenomena, as for example, atmospheric circulation and sea level changes, incidence of aurora, etc., require extensive observations of the kind fostered by IGY for as long as possible; (iii) observations of phenomena related to solar effects should be continued through the diminishing part of the solar cycle to capitalize fully on the IGY observations during the peak of the greatest cycle ever observed; (iv) to provide for the possibility of modifying certain programs to secure scientific information of greater significance and greater value to the elucidation of early IGY information; and, (v) to maintain international geophysical cooperation on an operational level to provide for continuity to future cooperative programs (oceanography, space exploration, Antarctic, Arctic, etc.) which are now being planned and for which international committees have been or may soon be established.

The Assembly recognized the needs for such continuation of geophysical cooperation, but it was also recognized that continuation of IGY as such was not possible because of factors such as prior commitments made by various participating committees to their governments. The Assembly decided, then, to suggest a new program, closely related to the IGY, and the following recommendation was formally adopted by the CSAGI:

"The observational and data-collecting activities in the geophysical and related sciences be conducted during 1959 on the same general plan as in 1957–58, under the direction of CSAGI or its successor, as far as practicable and at such level and in such fields as may be determined by each participating committee. The name 'International Geophysical Cooperation, 1959' is suggested for this period."

During its Eighth General Assembly, October 2–6, 1958, Washington, D.C., ICSU endorsed the CSAGI recommendation of IGC and established a new committee, the Special Committee for Inter-Union Cooperation in Geophysics, SCG, to succeed the CSAGI and to provide for coordination of international IGC–59 programs.

Action by the U.S. National Committee on the CSAGI–IGC Recommendation.—The U.S. National Committee, at a meeting on October 23, 1958, directed that its technical panels and project directors be polled as to their recommendations for a U.S. program for IGC–59. Several of the technical panels held meetings; for other disciplines the chairmen were consulted and project recommendations were developed. The Academy's IGY staff prepared a summary of all recommended proposals which were presented to the U.S. National Committee at its meeting on December 17, 1958. The Committee reviewed the proposed U.S. program for IGC, bearing in mind that rocket and satellite programs would be largely under the sponsorship of the NASA, and that the 1959 program in the Antarctic was already implemented. The proposed program was accepted as a feasible and desirable U.S. contribution to IGC with the understanding that in the short time available for the initial study, it was not possible to exhaust all possibilities of worthwhile projects for 1959. Throughout the development of this program, the U.S. National Committee kept Government representatives informed of the scope and fiscal requirements of the proposed program for 1959.

The program recommended by our Committee falls in three categories:

A. NETWORK ACTIVITIES

Many networks of stations will continue as normal programs of several agencies. These will form the basis for the IGC–59 program.

Meteorology.—Dr. Reichelderfer has informed us that support has been obtained for the continuation in 1959 of the five IGY upper air stations established in South America in cooperation with Chile, Ecuador, and Peru. The regular network of weather stations, of course, will continue and the Weather Bureau

agrees to contribute the data to IGC–59. The stations to be operated in 1959 are essentially the same as for IGY, with but a few changes in the polar areas (e.g., discontinuation of Little America).

Ionospheric physics—Vertical incidence.—The National Bureau of Standards, CRPL, has indicated that the following stations will be operated on a full basis in 1959: Belvoir, Huancayo, Talara, Puerto Rico, and possibly relocated stations at Cape Canaveral and San Salvador; stations to operate on a patrol basis (limited operations) are: Boulder, Barrow, Anchorage, Maui, Baguio, and Reykjavik; and support will be given to stations at Narsarssuak, Haifa, Stanford, and Godhavn. The Army Radio Signal Propagation Agency will continue Thule, Grand Bahamas, Adak, Okinawa, White Sands, and Fort Monmouth, and St. Johns will be taken over by Canada. CRPL will operate Chiclayo, Chimbote, and La Paz through March 1959; probably Bogotá but possible Concepcion will continue permanently. CRPL will also operate the radio noise network of stations throughout 1959.

Geomagnetism.—The U.S. Coast and Geodetic Survey will continue its regular observatories at San Juan, Fredericksburg, Tucson, Sitka, College, and Honolulu, and will continue operation of IGY stations at Barrow and Guam. Rapid run equipment will be continued at these locations with the exception of San Juan.

Oceanography—Tide gages.—The U.S. Coast and Geodetic Survey will, of course, continue operation of their network of tide stations some of which, at strategic locations, were designated as IGY stations. The Survey has agreed to supply 1959 monthly sea level data for these stations (mostly island locations) as a contribution to IGC–59.

B. FUNDED MAJOR PROGRAMS

There are two programs under this heading.

First, the Antarctic. This program, on a modest scale, is already underway under the auspices of the National Science Foundation. Dr. L. M. Gould, Chairman of the Academy's Committee on Polar Research, outlines both Antarctic and Arctic recommendations of his Committee in his statement.

Second, space science. Here in large measure the program of NASA is to be contributed to our IGC–59 and COSPAR efforts. Dr. L. V. Berkner, Chairman of the Academy's Space Science Board, will elaborate on these aspects.

C. SPECIAL IGC–59 PROJECTS

The only part of the program that requires special funding is this part. Here we have some 31 projects distributed among 12 fields which are intrinsically significant and represent most important components of our recommendations. A list of these projects, by discipline, follows:

1. Aurora and airglow

1.1. Observations at Chacaltayo Observatory, Bolivia, of the zodiacal light to study its spectral and polarization characteristics.

1.2. Continuation of the special airglow photometer at Thule, a location very close to the magnetic pole.

2. Cosmic rays

2.1. A balloon program for the study of correlation of solar activity with primary cosmic ray intensity.

2.2. The continuation of the neutron monitor and meson telescope at Thule, for the study of cosmic ray variations at very high magnetic latitudes.

2.3. The continuation of an air shower detector for the study of very high energy cosmic rays.

2.4. A program using very large balloons to study the composition and intensity of primary cosmic rays as a function of time.

2.5. The continuation of the neutron monitor at College, Alaska, as part of the study of the variation of cosmic ray intensity.

2.6. The continuation of the neutron monitor and special meson telescopes at Lincoln, Nebr., a location south of the area of low energy cutoff, as part of the study of cosmic ray variations.

2.7. A balloon program using miniaturized flight components for a study of soft radiation and primary cosmic ray flux at Resolute, Canada.

3. Geomagnetism

3.1 Continuation of the five-station network in South America for the study of the behavior of the equatorial electrojet.

4. Glaciology

4.1. Various programs in Western United States, including additional work on the heat and mass budget of the Blue Glacier, and glacier surveys in appropriate mountain areas.

5. Gravity

5.1. Completion of a set of additional gravity measurements necessary to tie together existing datums, and a program of analysis of gravity data in terms of crustal structure.

5.2. Continued observations of gravity at sea on surface vessels using the Graf special gravimeter, in connection with obtaining more information on the shape of the earth and relating gravity data to crustal structure.

6. Ionospheric physics

6.1. Continuation of networks of whistler stations in both Eastern and Western United States to study changes in whistler propagation in the period of decreasing solar activity.

6.2. Continuation of the network of backscatter ionospheric sounders as a synoptic program in the study of ionospheric irregularities.

6.3. Continuation of stations which record the incoming cosmic radio noise, as part of the study of changing ionospheric absorption in response to solar and magnetic effects.

6.4. Modification and continuation of the observations of ionospheric drifts and winds in the light of new theory and early IGY results.

6.5. To provide for the processing and publication of vertical incidence ionosonde data in accordance with international recommendations.

7. Longitude and latitude

7.1. To provide for additional astronomical observations at the Hawaiian stations to increase the reliability of the baseline determination: Washington-San Diego-Hawaii.

8. Meteorology

8.1. To provide for reduction of data from Arctic Drifting Station B and from antarctic stations as may be required for submission to the data centers.

9. Oceanography

9.1. To continue sea-level and wave-observing stations in both the Atlantic and Pacific to provide important additional data for the study of seasonal sea-level variations.

9.2. To provide for the study of spectra and propagation characteristics of long-period ocean waves at a specially instrumented pair of stations.

9.3. To establish three new sea-level observatories in the South Atlantic to complete worldwide coverage. These stations are needed to complement stations established during IGY in the South Pacific.

10. Rocketry

10.1. To provide for astronomical observations of the sun during disturbed periods (flare activity) using specially designed rockets which can be held on standby status and fired upon notice of an important solar event.

10.2. To assist in securing additional firings during 1959 at Fort Churchill, Canada, where many fundamental discoveries of high-atmosphere properties were made during IGY.

11. Seismology

11.1. To provide for calibration and standardization of the network of long-period seismographs, in order to increase the value of the worldwide study of the internal structure of the earth, using data from these instruments.

11.2 To continue the seismograph recordings at Truk in the Pacific, a region near important seismic areas, where few stations exist.

11.3. To provide for additional explorations of the earth's crust using explosion seismology.

11.4. To initiate a new comprehensive program of crustal exploration using close-spaced recording stations and carefully controlled explosions.

12. Solar Activity

12.1. To provide for continued solar patrols and rapid data reporting at the several key solar observatories which participated in the IGY program. This

includes both optical and radio detection of flares and also indirect flare detection through the observation of flare-associated propagation effects.

12.2. To provide for timely reduction of solar data and publication for the use of scientists in related fields.

In addition to these special research and patrol projects, the IGY World Data Center A and its 11 discipline centers, should remain in operation to receive data from IGC–59, and to insure that it is exchanged between centers in other countries and made available to the scientific community, in accordance with the recommendations of the CSAGI.

All of these projects, including the continued activity of the world data centers and the technical direction of the effort, represent a recommended expenditure of some $2.5 million.

Now this program which our committee has recommended is a sound, tight, minimum one. I do believe, however, that with the special funding—to the extent of about $2.5 million—of the special projects I have outlined, in addition to other efforts that require no special funding, this Nation would have a significant program from a science point of view and a meaningful one of the point of view of the overall information effort. Let me say that other nations are vigorously supporting IGC–59. Thus the U.S.S.R. intends to conduct a program at least as extensive as its IGY activity, as the following statement in Pravda, December 28, 1958, of Prof. V. V. Beloussov, vice president of the Soviet IGY Committee makes clear:

IGY Studies Continue

V. V. Beloussov, Corresponding Member, U.S.S.R. Academy of Sciences
(Vice President, U.S.S.R. IGY Committee)

"* * * The elapsed 18 months of the International Geophysical Year have fully confirmed the immense efficacy of the idea underlying its organization and have amply repaid the no small expenditure of material resources and human energy. This may be safely stated already now, though the elaboration of the obtained data is only beginning.

"Thanks to this broad international cooperation we have for the first time obtained a sort of motion picture of the most diverse geophysical processes simultaneously developing over the whole surface of the globe. This motion picture makes it possible to compare these processes and ascertain how they mutually cross influence each other. For instance, the meteorologists have for the first time in the history of science become able to compile synoptic weather charts covering the entire earth, which is inestimable for an understanding of meteorological processes.

"An analysis of the observational data will give us an altogether new idea about the interconnection of phenomena in the upper layers of the atmosphere, about solar activity, cosmic rays, aurora polaris, magnetic storms, and disturbances in the ionosphere. And a collection of the results obtained by the oceanographers, glaciologists, and meteorologists sheds new light on the heat and water balance of our planet. The joint work on general problems carried out by the geophysicists, specializing in different fields of this science, have produced a qualitative leap in our conception of the world around us. * * *

"After discussing the preliminary results of the IGY, its special committee, assembled in Moscow last summer, concluded that the exceptional opportunities opened to science would be far from fully utilized if the observations were terminated on December 31, 1958, as previously planned. By prolonging the operation of the already organized observatories for another year incomparably fuller data could be obtained with moderate additional outlays.

"The Moscow assembly of the IGY Special Committee, therefore, unanimously resolved to extend the joint investigations for another year, naming this additional year of observations, International Geophysical Cooperation of 1959. It was decided to retain the previously adopted programs, the established conditions for exchanging materials, and the central coordinating organizations. The Soviet Government has lent its support to the scientists' initiative in prolonging the IGY, and has allocated the necessary funds to enable Soviet scientific organizations to carry out just as intensive a program of observations in 1959 as the one pursued in the preceding year and a half.

"There is ground to assume that the scientists of other countries will likewise be no less active in the coming year than they were until now.

"The Soviet IGY Committee has approved a plan under which scientists of a hundred research institutions and higher educational establishments of our

country will continue in 1959 to observe the processes occuring in the bowels of the earth, in the oceans, and in the atmosphere. In 1959, IGY investigations will be conducted on a scale no smaller than in the previous years. Some 500 stations and observatories on the territory of the Soviet Union will continue observation of meteorological and magnetic phenomena, cosmic rays, disturbances in the ionosphere, solar activity, aurora polaris, and other geophysical phenomena, under all sections of the IGY program. The Soviet Antarctic expedition which will organize a new station, the Lazarev, in the still unexplored part of the Antarctic coast, will continue its work. Ten research ships will further develop oceanographic investigations in which new instruments of underwater observations will be used.

"While continuing their observations, our scientists will, in 1959, pay much attention to elaborating and scientifically analyzing the collected data. As is known, all the IGY investigation materials from all over the globe are collected at two world centers, one of which is already actively functioning in Moscow.

"A new fascinating field of activity is opening up before the Soviet scientists: Elaboration of the IGY scientific results of vast scale and unique value; discovery of new geophysical laws; the use of the newly derived theoretical conclusions in practice and their application to the needs of the national economy.

"To elaborate the IGY scientific results quickly and with the greatest effect, an appropriate organization of the scientific work is required. A great part here is to be played by new technical facilities, and by electronic computers, first and foremost. Some of the geophysical institutions will have to be reorganized internally, and reinforced. The Soviet IGY Committee will soon, after a further discussion, approve an interdepartmental plan for analyzing and elaborating the accumulated materials. This plan will focus chief attention on developing complex problems based on a comparison of the research results in different branches of geophysics. It is such contiguous fields of knowledge that now hold out the greatest promise of further scientific progress.

"Analysis of the materials will, of course, take a number of years. The results of the analysis made by Soviet researchers will be published for wide use in the special 'IGY Transactions' series, as well as in the 'IGY Annals,' an international publication.

"It is our task to continue maintaining a network of geophysical stations and observatories as well as other forms of geophysical investigation at a level conforming to the successes achieved and to the ever-growing importance of geophysics to diverse aspects of human life and activity.

"The progress resulting from the organization of the International Geophysical Year should be consolidated in the future. The Soviet geophysicists have always favored the development and strengthening of scientific contacts with their foreign colleagues. During the IGY Soviet scientists have done much to help establish a good friendly atmosphere among the participants in this great undertaking.

"The Soviet scientists will continue to do everything in their power for the further extension and deepening of international cooperation.

"We hope that our foreign colleagues strive for the same, and on their part will help to continue and strengthen the international scientific cooperation that has been carried out so well. The IGY has vividly demonstrated all the scientific benefits of such joint creative efforts by scientists of all countries."

I'd like to close by pointing out that the IGY has added much to its basic objective, that of mapping our physical environment. The pattern of activity of the IGY has led to some meaningful thinking about the national approach to science programs. The IGY has inspired scientists and others to plan for meaningful international cooperation in fields other than geophysics. It has had some notable byproducts in the fields of science education and the public awareness of the importance of science. What the future results of the research on the IGY data will be no one can predict. However, it is safe to say that these results will more than justify the large effort that has gone into the IGY.

Dr. KAPLAN. I would like first to thank Mr. Thomas and the members of the committee for allowing us to make another progress report on the IGY and I'd like to propose as the title of this report "The IGY—A Report to the Nation by the National Academy of Sciences."

I'd like also to express to the committee the gratitude of the Academy's IGY Committee, the many scientists and institutions in the Nation who have contributed to the IGY effort and the many others who have become interested in science through the IGY.

I am certain that the wisdom of the committee in supporting the satellite effort has advanced by several years the U.S. position in space research.

CONTINUATION OF IGY WORK

Mr. THOMAS. Would you forgive us if we were to interrupt you right there? You suggested it twice in two sentences.

We are as interested in these problems, as you are. Should the IGY be continued? Can you get that splendid 100 percent cooperation of these other 65 nations that you have had for the last 18 months in the continuation of this program for another year or year and a half or 2 years, or 3 years, or whatever length of time the results indicate that the activity should be continued?

Dr. KAPLAN. It is stated in my testimony, Mr. Thomas, in considerable detail, the origin of a continuing program, which is known as "IGC–1959," International Geophysical Cooperation, 1959, which started with a U.S.S.R. agenda item at the IGY meeting last summer in Moscow.

After considerable discussion the 66 nations agreed to continue a type of international cooperation known as IGC–1959 in which the various nations would do what they felt would be valuable, keeping in mind what we have had in the back of our minds now for some time, that this data should be tabulated, properly analyzed and the large area of interdisciplinary research opened up.

You will hear about some of that later from Dr. Roberts when he talks about solar-terrestrial relationships, for example.

Mr. THOMAS. What you are saying is that there has been an agreement to continue virtually for an indefinite period, the activities?

Dr. KAPLAN. No, this is not an indefinite period, but a year, 1959, after which a special committee of the International Committee of the Scientific Unions, ICSU, would continue the interunion cooperation to make sure that all of this data was quickly, properly analyzed, reduced and exchanged.

CONTINUATION OF ANTARCTIC PROGRAM

Mr. THOMAS. What does Dr. Gould mean in his telegram when he claims that the United States has given up its leadership in Antarctica? We haven't given up the bases. We gave them a supplemental last year of $2 or $4 million.

Mr. YATES. The current budget is $2 million.

Mr. THOMAS. We have an estimate for the curent fiscal year. If we are going to continue IGY under whatever name it may have, wherein have we given up our leadership in the South Pole area?

Dr. KAPLAN. Part of this IGC–1959, Mr. Thomas, is such operations as the space research program and the work in the Antarctic. I have not been personally concerned with the Committee on Polar Research, of which Dr. Gould is chairman.

Dr. BRONK. Mr. Chairman, Dr. Berkner has recently been in the Antarctic.

Dr. KAPLAN. He will be here later.

Dr. BRONK. I suggest you discuss that with him.

Mr. THOMAS. The doctor has been there a good many times.

Mr. YATES. May I interrupt a minute? I wonder whether you would answer Mr. Thomas' statement about Dr. Gould's telegram. As I recall the telegram, too, there was a statement that he deplored our giving up the Antarctic. What is the basis for Dr. Gould's statement?

Dr. KAPLAN. I would like much better for Dr. Gould to speak for himself here, but as I understand it, certainly the level of our operations in IGC 1959 in the Antarctic, for example, is not as great as the level of operations during the IGY.

Some other nations down there will probably continue operations on the same level. Certainly the U.S.S.R. intends to do that, according to a statement in Pravda.

Mr. THOMAS. Will Dr. Berkner tell us about this when he comes in, the level of activity in the polar regions?

Dr. KAPLAN. I believe so. He can do it better than I can.

Mr. THOMAS. You say Dr. Berkner?

Dr. KAPLAN. Yes, or Dr. Wexler will talk on it.

Dr. WEXLER. I am supposed to take Dr. Gould's place and I will touch on some of these matters.

Lloyd Berkner, because of his great love for the Antarctic, will have something to say about this.

TERMINATING ACTIVITIES OF THE IGY PROGRAM

Dr. KAPLAN. I would like at this point to go into perhaps a little more detail on the termination of our IGY program.

Mr. THOMAS. We are not going to interrupt you, you go ahead.

Dr. KAPLAN. Here I distinguish between the termination of the IGY program for which the committee appropriated funds and the proposed U.S. participation in IGC 1959. Those are two separate topics.

As far as terminating our IGY program is concerned, the following comments indicate where we stand:

First, the observational program is largely finished. As you will recall, some observational projects extend into this calendar year. Specifically, let me mention the Antarctic where summer studies extended into the early part of this year; the arctic ice floe stations where work similarly extended into the early part of this year; the IGY satellite program which continues to June 30, 1959, where, as you have heard, a successful cloud cover satellite was launched yesterday; and, in addition, there are a number of projects which the Committee believes should continue during the course of this year in several disciplines because they would valuably and significantly enhance the data taken during the IGY itself. This small group of projects, which requires no additional funding, represents expenditures of less than $75,000. Your concurrence in this orderly procedure, as strongly urged by the Committee, would be appreciated.

The second area to which I should like to make reference has to do with what might be called the nonobservational activity. This encompasses data reduction analysis. the activities of the world data

centers, the technical direction and management activities of the Committee and the staff, and the interdisciplinary research program. Here, as you know, an orderly procedure was developed in concert with this Committee and with the National Science Foundation. This procedure calls for the termination of the obligation of funds on the part of the National Science Foundation, acting upon the advice of the Committee, by June 30, 1960. This termination date for obligations has been discussed at almost every hearing which this Committee has held on the IGY. I still believe that this termination period for obligations is a satisfactory and proper one as concurred in by the Committee repeatedly. However, some activities may require an additional 6 months to a year for expenditures by the grant recipients beyond the date of June 30, 1960. For example, funds will go out to universities and private laboratories considerably before June 30, 1960. As a matter of fact, of the 1.75 millions for special interdisciplinary research, all but approximately $75,000 have already been allocated or granted to institutions and the balance is expected to go out very soon. But, their orderly prosecution of their theoretical and analytical researches may require their activity and, hence their expenditure of funds after June 30, 1960. This is particularly true in the interdisciplinary research program. You will recall that you appropriated funds for this purpose late in the last session of Congress; these funds became available about August of 1958; initial grants were made in December 1958; and, you will recall that we had discussed this theoretical and analytical research program as one that would require something like 2 years for execution.

SUMMARY OF IGY PROGRAM

(a) I would like, very briefly, to summarize my prepared statement. In this statement I point out the way in which the IGY was planned and operated. First the assemblies and conferences on the international level and the technical panels on the national level. The IGY has not only accomplished the basic task that was before it, that of mapping our physical environment, but it has extended the meaning of that phrase by opening the important fields of space science.

(b) The IGY has also left to science a legacy of plans such as those of SCORE, SCAR, COSPAR, IGC 1959 and SGC (the Special Committee for Inter-Union Cooperation in Geophysics).

(c) I can illustrate the spread and growth of interest in geophysics by the size of the audience at a recent American Physical Society symposium in which Drs. Friedman and Jastrow of the United States and Dr. Chapman, President of the CSAGI, participated. The audience not only filled the grand ballroom of the Hotel New Yorker, but some 75 people had to stand. This, in contrast with the relatively small number who attended upper atmosphere symposia only a few years ago.

(d) Some of the IGY results have been summarized in two articles in "Science" by the Executive Director of the United States National Committee for the IGY and my testimony also contains a summary of the current state of the data flow for each of the 11 subcenters of World Data Center "A", which the Academy operates for the IGY.

I would like permission to insert Mr. Odishaw's remarks before the National Press Club in the record.

Mr. THOMAS. Insert it in the record at this point.
(The information referred to follows:)

THE MEANING OF THE INTERNATIONAL GEOPHYSICAL YEAR

Members of the National Press Club and distinguished guests, I am pleased to be here today, sensible of the honor that an invitation from you holds. I am also sensible of the honor accorded me by the distinguished gentlemen at the head table; most of them are members of the U.S. National Committee for International Geophysical Year.

Now I am only, as Henry V put it, a warrior for the working day. But I understand that what you want is a personal assessment of the IGY from someone who has become completely enmeshed in its tentacles—a description which fits me perhaps all too well. This personal assessment, of course, is compounded of my own convictions and prejudices, cultivated over the last five exciting and consuming years.

My contention is a simple one: the IGY is the single most significant peaceful activity of mankind since the renaissance and the Copernican revolution. Accordingly it must and does have a variety of meanings. It has meaning in terms of (1) science, (2) its social significance as a pattern of activity, (3) its role in affecting the future, and (4) its general and intellectual implications.

1. MEANING TO SCIENCE

Although the IGY observational program is still underway, with all the limitations that this entails in terms of assessing its results at this time, the remarkable thing is what has already been achieved—and achieved on several levels. Three areas of accomplishment suggest its meaning to science: first, the mapping of man's physical environment; second, the interdisciplinary revolution; and, third, specific discoveries, clearly meaningful in themselves.

The basic objective of the IGY was a mapping of our physical environment. Just as geographic mapping has its self-evident necessity to man before he can know a region and before he can begin to assess and utilize it, geophysical mapping is a prerequisite to a scientific understanding of the earth and its cosmic environs. So the fundamental purpose of the IGY was the acquisition of synoptic data—data taken simultaneously on and about the earth in order to get a planetary view of weather, geomagnetism, the ionosphere; the aurora, and the like. In this objective the IGY has been fully successful—as the quantity and quality of data in the IGY world data centers prove. The reduction and analysis of these data have already begun, but it will be years before the value of these precious records can be fully realized and appreciated. Moreover, as time goes on and new and fundamental discoveries are made, these data shall often assume a new life of their own, because research scientists will re-examine this unprecedented storehouse of facts in the light of such new discoveries.

Aside from the obvious significance of obtaining a world-wide view of a particular field—for example, atmospheric circulation which is crucial to a better undertanding of weather and climate—the IGY program has been remarkably rich because its investigations included the principal fields of geophysics.

What this inclusion means is simply the following: that measurements were made which relate one field to another, permitting a better understanding of what happens in each field. In the area of high atmospheric physics, for example, the interplay between solar activity, cosmic rays, auroral displays, geomagnetic storms, and ionospheric disturbances—a complex drama of a host of phenomena and processes—was carefully studied. So too with oceanography, glaciology, and meteorology, which combine to make up the earth's heat and water budget.

The IGY has not only provided the basis for better correlations among these disciplines of science, but it has drastically altered the attitudes of scientists themselves. Their approach to problems of our physical environment has undergone a great change—from a discipline approach to an interdisciplinary one. To encourage this development, which recognizes the facts of nature, the IGY is now granting $1.75 million specifically for analysis and theoretical researches of this interdisciplinary character.

Any discussion of the synoptic objectives of IGY and of interdisciplinary relationships suffers because either it must be presented in general, as I have attempted to do, or many hours are needed. Fortunately, the third category dealing with the scientific aspects of IGY permits me to be both brief and

highly specific. This category relates to particular findings of remarkable significance. Let me enumerate a few.

1. Using seismic sounding techniques, IGY scientists have laid bare the nature of a considerable portion of the land mass of Antarctica. This region now appears as a complex of island and mountain chains, particularly certain coastal parts where a few mountains now protrude above the vast ice mantle but where, even were the ice to melt, some mountain chains would lie hidden beneath sea level. Moreover, there are increasing indications of a major division between east and west Antarctica. These studies are for the first time in history establishing the character of the least known continent in the world, whose area is some 6 million square miles.

2. Seismic measurements have also given us a better measure of the amount of snow and ice in the world. The old figure was about 3,240,000 cubic miles. So much more ice has been found in Antarctica, to depths of 14,000 feet—and bear in mind that Antarctica accounts for 90 percent of the total—that this figure must be revised upwards by about 40 percent, to some 4,500,000 cubic miles. If the earth's climate, which is dynamic as geological history shows, changes, the significance of this number is apparent. The revised figure is critical for the study of the delicate balance of the heat and water regimen of the earth.

3. Three major countercurrents in the oceans have been found and measured. One in the Atlantic flows beneath and opposite to the Gulf Stream, traveling at a rate of 8 miles per day some 9,000 feet beneath the surface. The second, at depths between 200 and 1,000 feet, flows against the surface equatorial current of the Pacific, transporting a billion cubic feet per second. The third lies beneath the surface 200 miles north of the Pacific Equator, transporting 1.5 billion cubic feet per second. These measurements add critical new elements to our understanding of the major circulation systems of the oceans, circulation systems which hold great significance for the dynamics of weather and climate and even for the location and quantity of food stocks in the seas.

4. In studying ocean bottoms, a vast mineral-rich region in the Pacific has been discovered. Millions of square miles of the southeast Pacific bear a surface-bottom sludge laden with nodules of manganese and iron with up to 1 percent of cobalt mixed with copper. The value of these minerals is estimated at about $500,000 per square mile, and the economics of dredging up the sludge appear promising.

5. Studies of ice coverings in both polar regions are shedding light upon weather and climate of the past. For example, during the last 50 years or so the amount of precipitation in the Arctic has averaged twice that of the Antarctic. These records are preserved in the ice layers, affording the opportunity to read them much as we read tree rings. The significance of these studies transcends historical interests; for these data are also clues to the future of weather and climate.

6. In meteorology, the IGY has provided the first census of Antarctic weather. Recording of temperatures to a low of at least —124° F. suggests the possible role of this vast continent of cold in world weather. Studies of temperature, pressure, humidity, and winds have provided data from which the influence of this region on world weather can be examined.

7. Using sounding rockets, H. Friedman discovered solar X-rays low in the ionosphere. These X-rays, rather than the ultraviolet radiation responsible for the general electrification of the ionosphere, extend downward the lowest, D-region of the ionosphere and increase its ionization to such an extent that radio blackouts occur. Friedman has recently, during the eclipse expedition, found the source of the X-rays to be the sun's corona rather than its disk while the absence of ultraviolet radiation during total eclipse, noted in one rocket study, suggests the disk as the source of ultraviolet light. These findings have marked value for ionospheric physics in general and radio communications in particular.

8. During several voyages to Antarctica, supplemented by balloon studies and an aircraft flight around the equator, J. A. Simpson and his colleagues found deviations in cosmic ray trajectories from those to be expected using the classical description of the earth's magnetic field in space, which should uniformly affect paths of charged particles. The Simpson equator for cosmic rays turns out to be skewed westward by as much as some 45°. This points to perturbances of the earth's magnetic field by other magnetic fields in space, probably associated with recurring clouds of solar particles.

9. Discovery of the Van Allen radiation zone indicates that a vast region of space around the earth is populated with charged particles, probably replenished by solar plasmas. Trapped in the earth's magnetic field, leakage of these parti-

cles appears associated with geomagnetic variations and auroral displays. The discovery is of striking basic significance and of interest in terms of space exploration in the popular sense.

10. Throughout the IGY period the sun was kept under perpetual watch every minute. One purpose was the detection of solar flares in whose wakes frequently follow important effects in the upper atmosphere. But in addition photographs in the light of hydrogen were taken each minute, and sometimes more often. These provide a fabulous record of the history of the sun during the IGY period of sunspot maximum. The prospects of research, both into solar processes and into terrestrial correlations, using this unparalleled record seem immense to astronomers.

11. The successful launching of artificial satellites in the IGY program is a pioneering and historic event per se. It has ushered in the space age. It will inevitably lead to greatly increased knowledge of the earth and the solar system. The space age, taken in its fullest technical sense, means that a new era of science is opening up, with all that that suggests.

One must remember that these specific discoveries are the results of preliminary inspection of only a small portion of the total data. Add to the total data the compounding effects and vast implications of interdisciplinary studies, and there can be no question of the scientific import of IGY.

Let me venture two additional observations:

First, a matter of anticipation. I have not the slightest doubt, quite aside from space science, that we are on the verge of many new and radical developments, foreshadowed by what has happened in the three categories I have mentioned.

Within a century or so the oceans can become serious competitors of the continents in terms of material resources.

Within the same period it is likely that the energy and material resources of the deeps of the earth will initially be tapped.

Well within the same period it is conceivable that new and fundamental discoveries of solar processes will revolutionize our approaches to man's energy problems.

Now these opinions are based upon what has happened, upon what appears historically the consequences of research, upon what appears theoretically reasonable. The opinions may prove wrong but if so, other quite similar events will or can occur—always provided we continue to search for answers in nature.

Whether in fact we do continue the search is not self-evident. I feel strongly that we are plagued by frozen attitudes which may preclude right thinking and right action. We are polarized within our culture by two extremes: either we fall back on daydreams fed by "space cadets" who for one reason or another prophesy all types of materialistic advances ever so easily and simply and inexpensively, or we are congealed by the cash-results-today approach of those who cry for applications and practicality.

Second, I hope very strongly that one of the byproducts of IGY may be this: That it drive the last nail in the coffin of the juvenile and dangerous argument over the value of basic research. Scientific advances, whether national or international, can no longer be sustained on a crash basis or by gifted tinkerers. They depend almost exclusively upon the rewards of basic research. The mere symbols of basic research have become fantastically powerful in recent years.

2. PUBLIC AFFAIRS AND IGY

The IGY has had a double impact upon society, first as a purely scientific enterprise, and this I have already briefly discussed. The IGY also has overriding significance as a purely human engagement, as an activity of man without specific reference to its subject matter. I say overriding significance because almost alone among human enterprises it achieved remarkable international cooperation among 66 nations in a period of sharp and perhaps unparalleled political unrest.

What then was the IGY as such an activity?

First, it was not a government program, although governments at home and abroad supported it generously. Second, it was not a military program, although the military establishments of many governments, like our own, provided a variety of logistic support. Third, it was not an "internationalized" program, even though one of its greatest achievements was in the field of international cooperation. The very fact that it was none of these things accounts for a large measure of its success, scientific and international.

What it was and what it is is this: A gathering together of private human beings, each of whom had a vital personal interest in a particular subject, each of whom felt that this subject needed, out of its own exigencies, a concerted attack, but one for which a simple, uncluttered mechanism would suffice.

Thus the IGY was at root an enterprise of private persons, an enterprise in the hands of doers, and the form and shape it took largely reflect this. This form and this shape reveal much about the character of the IGY and may well afford a pattern worth noting, worth using again in other areas.

Look first at the international structure of IGY. The International Council of Scientific Unions, under whose aegis the international effort was coordinated, is a nongovernmental body. Its private as against official nature is a known fact. The CSAGI, the special committee that ICSU established for IGY, achieved international coordination through general assemblies of experts from the participating IGY committees in various parts of the world. The criteria for this unprecedented study of the earth, and the broad program, were worked out by these experts.

No elaborate bureaucracy was called for or established. CSAGI is temporary. Its officers are temporary and unpaid. Its small secretariat is temporary.

Deliberations at the general assemblies suffered from no obvious considerations of national "face," or considerations of official positions in other areas or at other times, as formal governmental deliberations inevitably appear to do. Energies were directed to the restricted problem at hand. By and large, the problem's own objectivity led to objectivity in discussions, conduct, and actions.

It is for these reasons, in my opinion, that the IGY succeeded brilliantly in marshaling international cooperation. Yet within this framework competition was not lacking: Indeed, competition helped. While internationally agreed upon criteria established the basic content of the program, the burden of execution rested upon national groups, which naturally wished to do well. Even more fundamentally, the burden fell upon individuals, who were personally interested in their part of the program and were individually anxious to achieve meritorious results.

For these reasons, some 30,000 scientists and technicians, and an equal number of volunteer observers, spread from pole to pole at 4,000 principal scientific stations and an equal number of secondary sites, representing 66 nations and marshaling their support, succeeded in the conduct of this 18-month adventure into the unknown.

The character of this enterprise is gaining recognition. In our own Congress, during hearings before the subcommittee of the Committee on Appropriations of the House, the chairman, Representative Albert Thomas, said, and I quote the record: "I think you gentlemen of the International Geophysical Year have set a pattern of worldwide cooperation that nations and governments, and particularly our good State Department, can take a leaf out of your book."

On a national level, also, the IGY has established a pattern largely new to the country. The American program, as generally in other nations, was planned, and directed by a national, nongovernment committee. The Committee and its panels actually comprised a coalition of experts vitally concerned with geophysical research. The scope of our program was established by three sets of contributions: First, the existing programs in public and private laboratories, especially the networks in geomagnetism, meteorology, and ionospheric physics of the Coast and Geodetic Survey, the Weather Bureau, and the National Bureau of Standards; second, the special stations and facilities made possible by $43.5 million appropriated by the Congress through the National Science Foundation; and, third, contributions from private institutions, particularly universities. Each of these represents about a third of the total research effort. Very important and extensive technical and logistics support was contributed by the Department of Defense, particularly for the Antarctic, the Arctic, rocket and satellite efforts.

Very simply, the scientific community, assembled as individuals by the National Academy of Sciences, without regard to their institutional affiliations but only with regard to their competence and interest, established what needed to be done and then called for such support, both financial and logistic, as they needed from every available source.

It appears now that this was an excellent way in which to do a job so broad in scope. Whether the pattern will be followed in other ventures, including even scientific ones, remains to be seen.

3. THE IMMEDIATE FUTURE

The future influence of the IGY has many aspects, and its progeny are destined to be highly variegated as well as numerous. The most immediate scientific offspring seem to be five in number.

1. International cooperation in geophysical research will certainly continue for an indefinite period. While the IGY as such ends this calendar year, plans are underway for continuing through another year the kind of cooperation and activity that marked the IGY. This program is called International Geophysical Cooperation—1959 (IGC–1959). The International Council of Scientific Unions has established a Special Committee for Interunion Cooperation in Geophysics (SCG) which will assume responsibilities for IGC–59 similar to those that CSAGI assumed for IGY.

The program for 1959 will consist in part of continuing geophysical research programs in various nations, marked by international cooperation in the observational aspects and by data interchange as in the IGY. By "continuing geophysical research programs," I am referring to two types of activity: first, the permanent networks of stations in such fields as meteorology, ionospheric physics, seismology, and geomagnetism; second, a variety of research projects, particularly in the midlatitudes, in many fields of geophysics, which would be conducted even were there no IGC–59.

While some rather modest needs exist for additional research in the midlatitudes, the supplements to the above effort, thus making up the total, stem largely from the following four other specific endeavors under new and separate auspices.

2. The sheer size of the oceans, our current ignorance of them because of this and in spite of the oceanographic accomplishments during the IGY, and the need to learn more as rapidly as possible about them, led to the establishment of a Special Committee for Oceanographic Research (SCOR) by the ICSU. This new committee has planned a program emphasizing sea level, circulation, and sea floor studies. The American counterpart to this international body is the Academy's Committee on Oceanographic Research under the chairmanship of Dr. Harrison Brown of the California Institute of Technology.

3. Even 2 years of IGY could represent no more than a good start on the scientific exploration of Antarctica. For such reasons ICSU established the Special Committee for Antarctic Research more than a year ago, and a continuing international effort has been planned. In the United States, the Academy's Committee on Polar Research, under the chairmanship of Dr. L. M. Gould (president, Carleton College), developed a $2 million program for 1959, which has been implemented by the National Science Foundation and the Navy. This committee has also looked into the north polar scientific needs.

4. Another special program, calling for continuation of what was done in the IGY, relates to a watch on the sun. The program of solar patrols and alerts proved most rewarding during the IGY. The ICSU has arranged for the international continuity of this effort, establishing the International Service for World Days, as the program will be known.

5. Recognizing the importance of international cooperation in space research, the ICSU established last October the Committee on Space Research (Cospar). This Committee had its first meeting at the Royal Society in London last month when it established its own working procedures, outlined its program, and set up working groups concerned with (i) space experiments, (ii) tracking and communications, and (iii) data interchange and publications. The Committee elected its officers, consisting of a President, Dr. H. C. van de Hulst, of the Netherlands, and two Vice Presidents, Dr. W. Albert Noyes, Jr., of the United States, and Academician E. K. Federov, of the Soviet Union.

In the United States the counterpart to Cospar is the Academy's Space Science Board under the chairmanship of Dr. Lloyd V. Berkner (president, Associated Universities, Inc.) The Board and its committees represent a complex of some 100 scientists, who have been studying space science needs and prospects, serving as advisory to the several Government agencies which will implement the program.

4. GENERAL IMPLICATIONS

IGY results already at hand suggest that it has opened new doors for man in relation to his environment. Some of these are specific research doors, for as new insight is gained into nature, new questions come to mind, and many major, specific scientific endeavors challenge the scientists. Other doors open up possibilities relating to resources as in, for example, the intelligent exploitation of the seas. But doors of an intellectual and psychological kind can also be opened by imaginative and far-reaching enterprises of the type that IGY has been. It is in this area that I should like to make two remarks.

First of all, I believe that the IGY has greatly extended the physical and psychological frontiers on earth. In spite of, and perhaps precisely because of, the results accumulated during the IGY, it is clear that we have only scratched the surface of our ignorance with respect to Antarctica, the Arctic Basin, the oceans that cover 70 percent of the earth, and the depths of the earth itself. In my opinion, the drama and romance of the IGY have contributed to a recognition that much exciting work remains to be done on earth itself: (1) Some of this work has the nature of exploration in almost the common sense. (2) Even more important, however, is the challenge of detailed scientific exploration.

Of course, the fact that these two almost unlimited horizons have always existed was no secret before the IGY, but this is beside the point. As a result of the IGY, countless people, including many scientists, have a new and invigorating attitude toward our planet.

Second of all, I need not emphasize that the age of space affords a limitless frontier to the human mind and spirit. The pursuit of knowledge of the universe, using the tools now at hand, will occupy the interests and energies of innumerable men as they reach, no longer earthbound, far into space. The drama and excitement here, if but properly construed, are incomparable, and the ultimate place of IGY in history may be as the initiator of space research. History may well regard this innovation as the most striking departure of men in this or any century.

For these two reasons then—the new horizons on earth and those beyond earth—it appears that another renaissance can be ours. Now, the Renaissance was not merely the revival of learning, it was that coupled with much else. Of the latter, one of the most provocative ingredients was new knowledge about new lands and new waters.

Looking back, we can see that the period following Columbus' discovery of America was charged with an excitement stemming in large part from the adventures on strange waters and unknown lands. This excitement and these discoveries were apprehended broadly and generally, entering into the imagery of poetry and influencing almost every aspect of life.

Again looking back, we can see that the Copernican astronomy achieved not only a revolution in science but changed man's concepts of man, of his religion, and of his philosophy, and the impact of heliocentricity was felt over the course of several generations.

The onset of the space age affords the possibility of a comparable impact.

It may be argued that the new astronomy of Copernicus had its large effect because it was an important scientific discovery while space is not a revolutionary discovery: it has been there all along and all that has happened is the availability of engines that can travel there. To this the answer is twofold.

First, that space has no meaning unless realizable, and its now being tangibly within reach is intellectually and emotionally comparable to the impact from the findings of Copernicus: To be at the threshold of an age which releases man from the confines of his ancestral, primordial, planetary home is no small matter.

Second, the very fact that the results of man's coming space ventures are still unknown and mystery laden to him, only furnishes added intellectual provocation.

Provided that the complexity of modern society does not hide what is at hand, provided that the destructive forces present in our day not only do not eliminate civilization but do not, by their necessary insistence upon man's attention, mask the wonders of earth and universe, and provided that teachers and poets, scientists and philosophers sense the possibilities, there is at hand an unparalleled situation for stimulating the best in man.

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International Geophysical Year

(The first of a two-part summary of IGY activities covers studies of the sun and upper atmosphere)

(By Hugh Odishaw[1])

An earlier report outlined some of the activities of the IGY, especially as reflected in our own program, during the first months of the endeavor (1). Here an attempt will be made to narrate, on behalf of the IGY scientific community and based upon their reports to the National Academy of Sciences, some of the events as the IGY reaches its formal close on December 31, 1958 (2). Just as the earlier report could be only suggestive, this too can but touch upon a few of the happenings, largely within the U.S. program, but perhaps some feeling for the whole effort can be conveyed. Some of the work described here has been reported in the scientific literature, and various papers are in press or preparation. IGY bibliographies are being prepared by several agencies; they now exist in interim and draft form (3, 4.)

The magnitude of the effort was appreciable, and some statistics show this clearly. For example, table 1 presents the number of principal stations in each activity, grouped by latitude zone and indicating the degree of geographical coverage that was attained. The total number of stations is incorrect because there is duplication where projects in two or more fields were housed in a single structure. The correct total, in the sense of the table and based on the CSAGI geographical distribution list of June 27, 1958, turns out to be 2,461, but this too fails to present the whole picture: First, from a scientific point of view, the uncorrected table number of some 3,500 stations is more truly representative of the total station activity. Second, some stations were added after the compilation of the list. Third, many temporary stations, all surface meteorological stations (about 2,500), and perhaps 1,000 auroral and satellite volunteer observation stations and sites have been excluded. The best that one can do, therefore, is to say that some 4,000 principal scientific stations and several thousand contemporary and volunteer sites or stations were active.

Similar difficulties beset one in establishing how many individuals took part in the IGY or in estimating the costs of the overall effort. Both of these difficulties stem in part from the variety of ways in which the various national committees funded their programs and from the extensive voluntary contributions made by public and private institutions. It is probable that some 20,000 to 30,000 scientists, engineers, and technicians were engaged in the effort, supplemented by a somewhat comparable number of volunteer observers.

The story that can now be told encompasses three aspects of the IGY: (i) The discoveries and specific results that can readily be interpreted; (ii) the synoptic effort, which yielded vast quantities of data; (iii) the direct impact upon coming geophysical programs. In this article, the sampling is concerned with the upper atmosphere and the sun. Part II will similarly survey the heat and water regimen, the earth sciences, the synoptic data aspects, and post-IGY developments, particularly those for 1959.

Studies of solar activity, aurora and airglow, cosmic rays, geomagnetism, and the ionosphere provided a wealth of data and many concrete, striking findings. The simultaneity of the observations and measurements, which the IGY emphasized, proved invaluable, while the availability of rocket and satellite vehicles remarkably augmented the information secured from ground stations and observatories and balloons and aircraft. (See figs. 1 and 2.)

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SOLAR ACTIVITY

Studies of the sun during the IGY may be divided into two groups, regular surveys and special researches, even though the former also has important research values.

More than 100 patrols—visual, optical, photographic, photometric, and radio—kept the sun under constant watch at every minute throughout the IGY period. This unprecedented watch on the sun yielded ample returns. It permitted the detection of solar flares, and such information was channeled by solar observatories to the IGY World Warning Agency in the United States, where daily analyses were made of the likelihood of a solar disturbance with ensuing terrestrial effects. Between June 28, 1957, and November 30, 1958, these analyses led to the calling of 38 alerts—messages radioed throughout the world calling attention to the probability of the declaration of a special world interval. These intervals, of which there were 20 between June 28, 1957, and November 30, 1958, permitted scientists everywhere to intensify their measurements during the great periods when high atmospheric disturbances followed in the wake of major solar flares.

Chosen because it coincided with the current maximum of the sunspot cycle, the IGY period witnessed the greatest level of solar activity in history: The Zurich Observatory, international clearinghouse for sunspot statistics, reported that 1957 had the highest yearly mean in relative sunspot numbers since 1778, while the level of activity during 1958 seems to have been somewhat lower. The maximum of the present cycle fell almost in the middle of the IGY period.

In the patrol program photographs of the sun were taken by many observatories—every minute and even more often—in the light of hydrogen and calcium lines. These photographs, in effect a time-lapse study of the solar disk, provide, together with other related observations, the most detailed record of the sun in history. Taken during the greatest cycle of sunspot activity ever observed, this corpus affords a great body of information for astronomical analysis.

One of the new devices used in the solar program was the K-coronameter, used to measure the brightness of electron-scattered light in the K- or electron-corona of the sun. Much fainter than the emission corona of ordinary atomic transitions, the K-corona requires unusually clear skies. Some 50 such days at the high altitude observatory climax station yielded previously unobserved details of the sun. W. O. Roberts reports that variations of the depths of the layers of the corona, where temperatures of 1.5×10^{6}°K., prevail and where appreciable solar radio noise originates, were studied.

At the high altitude observatory, a line profile spectrograph has yielded some interesting data. D. E. Billings has completed a pilot analytical study which shows promising preliminary results on analyses of line spectra in H-alpha of about 50 small flares. Billings has produced a detailed graph of the optical depths of the flare gases as a function of wavelength, from the center of the spectrum line into its wings. Observatory scientists believe that if it proves possible to extend this kind of analysis to other flares, the results will be of the highest importance in flare physics. Such work will have a crucial bearing on problems of flare emission at wavelengths beyond the visible and on studies of the effects of flares in the earth's upper atmosphere and on geomagnetic disturbances.

H. Smith and his associates at Sacramento Peake Observatory report that a detailed discussion of the physics of the flare of September 18, 1957, is in process. The flare was photographed with the Sacramento Peak universal solar spectrograph covering 3,878 to 7,200 angstroms, with dispersion of 2 angstroms per millimeter and exposure of 3 seconds. The analysis of the observation showed a marked red shift, indicating a downward motion of material toward the solar disk. Twenty different ions were detected in the flare spectrum, and excellent profiles were obtained for the heavier lines.

TABLE 1.—*General list of principal IGY stations (from CSAGI Geographical Distribution List, June 27, 1958)*

	World days and communications	Meteorology	Geomagnetism	Aurora and airglow	Ionosphere	Solar activity	Cosmic rays	Longitudes and latitudes	Glaciology	Oceanography	Rocket and satellites	Seismology	Gravimetry	Nuclear radiation	Totals
Arctic (Φ>60°N or φ>60°N)	4	158	46	77	51	2	19	2	31	16	7	23	13	43	492
Subauroral North (60°N>Φ>45°N except if φ>60°N)	18	358	56	42	66	63	38	37	12	46	21	83	37	160	1,037
Minauroral North (45°N>Φ>20°N)	20	270	46	19	54	39	34	23	10	74	21	86	40	90	826
Equatorial North (20°N>Φ>0°)	10	89	18	4	33	9	8	4	------	50	5	35	9	30	304
Equatorial South (20°S>Φ>0°)	9	96	20	5	28	6	9	4	6	29	8	39	8	26	293
Minauroral South (45°S>Φ>20°S)	6	100	12	3	23	7	7	8	5	57	8	43	18	41	338
Subauroral South (60°S>Φ>45°S except if φ>60°S)	1	13	6	8	11	1	7	1	1	17	1	8	6	9	90
Antarctic (Φ>60°S or φ>60°S)	1	34	19	23	18	------	6	------	38	12	5	15	19	1	191
Total	69	1,118	223	181	284	127	128	79	103	301	76	332	150	400	3,571

Measurements of the Sun's surface magnetic field were made at Mount Wilson Observatory, revealing very high fields associated with some sunspots—as much as 8,000 times the Earth's field at the Equator. H. D. Babcock and W. C. Livingston reported that the south magnetic pole of the Sun reversed its polarity and that the north pole intensity decreased: these events have a timelag of some 3 years with respect to minimum sunspot count. Mount Wilson scientists believe that variations of the Sun's field probably reflect large-scale patterns of circulation related to the 22-year solar magnetic cycle, and they seem to be related to various solar-terrestial phenomena.

AURORA

The IGY period was remarkably rich in auroral observations. C. W. Gartlein (Cornell University), responsible for the visual observations program in the United States, reports that in the first 6 months of the IGY there were 103 nights on which auroras were seen in the United States. In the first 6 months of 1958 there were over 110 nights on which auroras were seen. In March 1958 auroras were seen on every night except that of the 31st.

Auroral activity was also monitored by all-sky cameras, radar, and absorption equipment (see fig. 3). The absorption program has turned up some interesting information that possibly bears on emission of soft cosmic rays from the Sun during flares. H. Leinbach and G. Reid (Geophysical Institute, University of Alaska) report that absorption records from Thule and two locations in Alaska, following a solar flare, give strong suggestion of solar cosmic ray emission at low energies. The absorption equipment, a relatively simple and reliable noise receiver, promises to play an important role in the study of the relationships of auroral, ionospheric, and solar phenomena.

A new twilight phenomenon, the presence of a line at wavelength approximately 6,700 angstroms, has been discovered in spectra taken in Antarctica during the last few months of 1958. First reported by the joint New Zealand-United States station at Cape Hallett on August 5, 1958, the radiation has been observed at all the U.S. antarctic stations with the exception of Little America, and by the New Zealand station at Invercargill. This radiation has been attributed to lithium in the high atmosphere, a constituent not previously known to be present there. The twilight display is evidently analagous to the familiar sodium twilight radiation often observed. A plain inference is that these new manifestations could be related to nuclear tests carried out during the same period as the IGY program.

At a recent meeting of the USNC-IGY Technical Panel on Cosmic Rays there was discussion of the suggestion by E. P. Ney and P. J. Kellogg of the University of Minnesota that a large nuclear explosion might result in some permanent perturbation of the Earth's external magnetic field. Although it was recognized that the energy contained in the external field is a small fraction of that in the internal field of the Earth, Ney and Kellogg pointed out that the total energy contained in the external field is of the order of that in a large nuclear explosion, which suggests the possibility of appreciable effects. No a priori reason was advanced why this could not take place. The temporary effects would disturb the trapping conditions for the Van Allen particles and, allowing their release, could produce an aurora. (In this connection it is interesting to note that A. L. Cullington of New Zealand has recently reported the observation, at Apia on August 1, 1958, of a manmade or artificial aurora (5).)

The interdisciplinary value of the simultaneously conducted IGY studies, often already indicated, is perhaps most strikingly suggested in the report of scientists at the University of Minnesota (J. R. Winckler, L. Peterson, R. Hoffman, and R. Arnoldy) on the great auroral storm of February 10–11, 1958, summarized as follows:

Balloon-borne instruments at Minneapolis detected two groups of strong X-ray bursts during the storm. These coincided with two large magnetic bays, with strong absorption of radio noise, and with the passage across the zenith of a very large amount of auroral luminosity. A cosmic ray decrease also accompanied the storm. The University of Minnesota workers believe that these terrestrial disturbances were associated with the earth's entry into a large cloud of solar gases that may have originated in a solar flare occurring about a day earlier.

The aurora observed in North America during this storm was one of the most spectacular in recent years. It was reported as far south as Cuba. At Minneapolis, the aurora was seen by visual observers simultaneously with the sudden commencement of the magnetic disturbance at 0126 U.T. on February 11. The all-sky camera record from Hanover, N.H., shows its appearance a few minutes after the magnetic disturbance began. At Minneapolis, from 0130 to 0330 U.T., a very intense diffuse green arc covered the sky from 20° above the northern horizon to the zenith and from the eastern to the western horizon. The outstanding feature, however, was the red color, also very intense, which appeared in diffuse patches at high angles above the northern horizon and, at 0200 U.T., covered the northern sky from 15° to 30° elevation as a diffuse arc.

The southern limit of arc forms reached a geomagnetic latitude of 46° N. at 1000 U.T. on February 11, 1958. It is estimated that the aurora extended from a height of about 200 to 800 kilometers, and for a distance of about 9,600 kilometers east-west and 400 kilometers north-south. In addition to a very high intensity of both the red and green spectral lines, other unusual features of the aurora were the diffuseness and extent of the luminescence and its persistence for long periods without major changes in form. Spectra taken in Alaska by scientists of the Geophysical Institute showed unusually strong development of infrequently noted emission lines. The outstanding solar event of the period preceding this aurora was a flare, reported by Honolulu Observatory as class 2 and by Sacramento Peak Observatory as 2+; this flare started at 2108 U.T. on February 9, and ended at 2302 the same day, with its maximum phase at 2140. Nevertheless, since considerable solar activity was present for several days prior to the terrestrial storm, the solar-terrestrial relationship is not completely certain. Large radio-noise fluxes were reported by several stations during the flare.

The terrestrial effects of this storm began at 0126 U.T. on February 11, according to the rapid-run magnetogram of Fredericksburg (Va.) Observatory. The horizontal component (H) of the earth's magnetic field immediately showed a bay of $+117\gamma$, followed by a disturbed period and a second sharp, positive bay of about 500γ, which appeared at 0159. This sudden increase in the horizontal component was accompanied by sharp drops of about 150γ in the vertical component (Z) and 30γ in the magnetic declination (D). It is assumed that these pulses represent the initial encounter of the solar gas cloud with the earth's dipole field or the sudden appearance of ionospheric current systems, or both.

Large earth currents were observed coincident with the horizontal-component peak at 0159. T. E. Talpey (Murray Hill, N.J.) has stated that the earth's potential at the western end of the North Atlantic telephone cable from Newfoundland to Scotland dropped from a maximum of about 2,650 volts at 0202 U.T. on February 11, through zero to a peak in the opposite direction at 0209. The current was driven from west to east through the cable and seemed to be an induction effect associated with the second magnetic peak.

The circuit loop of the earth current, if considered to lie in a vertical east-west plane, requires a return path through the sea above the cable. However, derivation of the potential in the water gives only about 15 volts around the circuit, compared with the measured maximum of 2,650 volts.

Thus the earth current was apparently part of a system flowing in the earth's surface and associated with changes in the vertical component in an unexplained way. The current system seems to have been centered over the Eastern United States

A balloon launched at Minneapolis at 0445 U.T. on February 11, encountered the first detectable X-ray bursts at 0622, coincident with the major decrease in the first large magnetic bay of the second phase of the storm; these bursts continued until 0730. A second large period of bursts occurred at 0850, coincident with the second magnetic bay of this phase.

It is thought reasonable to assume that both the changes in conductivity of the ionospheric E-layer, which produced the magnetic bays, and the observed X-rays had a common origin in electrons produced by the solar gas stream. Their energies would lie in the range from 40 to 100 kilovolts or higher; most of their energy, however, would be lost in the atmosphere as ionization and as the visible auroral light. About one one-thousandth of the energy would be radiated as bremsstrahlung X-rays, the higher energy components of which are detected at balloon levels (about 100,000 feet).

Large absorption of cosmic radio noise at 18 megacycles per second at Boulder, Colo., was observed exactly coincident with the magnetic bays and the X-ray bursts. The records give evidence of a very widespread increase in ionospheric electron density extending north-south for at least 150 kilometers. The correspondence of data from Fredericksburg, Minneapolis, and Boulder (fig. 4) shows that the major primary fluctuations were simultaneous over distances of thousands of kilometers.

The large changes in the horizontal component of the magnetic field, the strong cosmic-noise absorption, the auroral X-rays, and the general presence of the aurora itself are all consistent with a very intensified bombardment of the ionosphere by high-energy electrons between 0530–0700 and 0830–0930 U.T. on February 11, over Central United States.

It is interesting to note that, on the basis of the auroral electron flux (6 times 10^6 electrons per square centimeter, per second) inferred from X-ray intensity and energy, the electron density at Boulder coincident with the February 10–11 aurora is computed to be 1.2 times 10^5 electrons per cubic centimeter. This is in reasonable agreement with the value of 1.4 times 10^5 electrons per cubic centimeter obtained through cosmic-noise absorption studies on the assumption that absorption during an auroral storm occurs mainly in the upper D-layer, at altitudes of 80 to 90 kilometers.

There is, however, a discrepancy between visual estimates which placed the lower limit of the auroral luminosity at 200 kilometers and any suggestion that soft X-rays in the form of bremsstrahlung produced at this level might be responsible for the D-layer electrons causing noise absorption. This arises because there is insufficient X-ray radiation produced as bremsstrahlung to account for the lower level ionization if the limit of luminosity marks the lowest level of penetration of the electrons or other primary ionizing agent.

Therefore, either the estimated height of 200 kilometers was too high and the lower border of the aurora was actually at the usual height of 75 to 100 kilometers, or electrons or other particles carried considerable energy downward, below the visual auroral border.

The storm was accompanied by a worldwide Forbush-type decrease in the intensity of galactic cosmic rays as demonstrated by recordings of two groups of ground-level neutron monitors: one in Europe and Africa, close to the longitude of Greenwich, except for a station at Hobart, Tasmania (longitude 145° E.), and the other in the Western Hemisphere extending from Northern Canada to the Antarctic approximately along 90° W. All stations showed an initial drop at 0200 U.T. on February 11, of roughly the same amount, 4 to 6 percent. An interesting feature of this Forbush-type decrease, apparently reported for the first time, was a "precursor" drop in intensity that occurred closely coincident with the sudden commencement of the magnetic storm, at 0127 U.T.

High altitude soundings with a standard ion chamber and counter were taken before, during, and after the decrease. The total influx of cosmic-ray energy, obtained by integrating the ion chamber rates throughout the atmosphere, dropped 14.9 percent during the storm; by February 16 it had recovered to within 8.4 percent of the February 8, value.

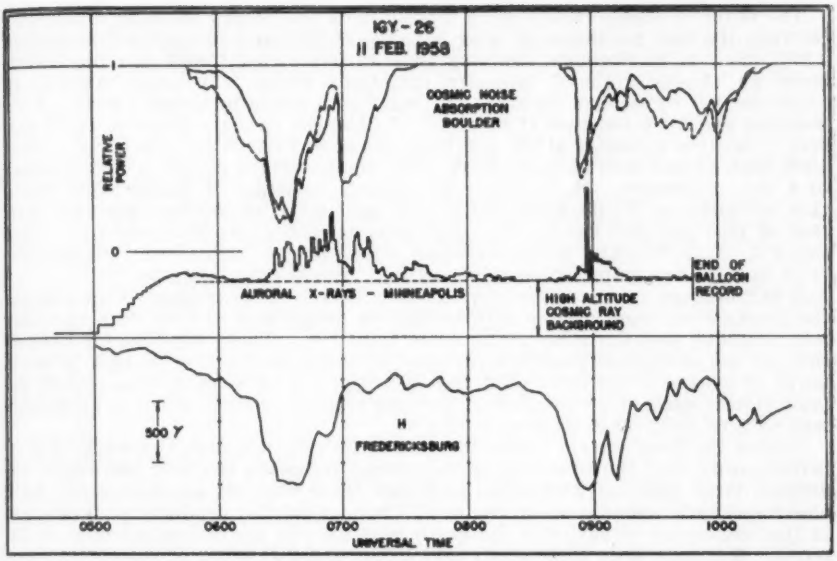

FIGURE 4.—Comparison of the horizontal field at Fredericksburg, auroral X-rays measured at Minneapolis, and cosmic noise absorption measured at Boulder. Two cases of intense ionospheric ionization apparently occurred, reaching maxima at approximately 0630 and 0900. The ionization was very widespread, as shown by this correlation and by all-sky camera photographs.

All the phenomena described are consistent with the passage of the earth into a remarkably intense solar cloud, which may have originated in the solar flare beginning at 2108 U.T. on February 9 and ending at 2302 on February 9.

If the cloud originated with the 2-hour interval of the flare and required 24 hours to pass the earth, considerable velocity dispersion must have been present in the solar gas so that the slower solar particles could predominate later in the storm. The leading edge of the cloud must have been exceedingly well defined, and the cloud must also have contained considerable internal structure, as revealed by "spikes" in the first phase and by the two large bays accompanying the X-ray bursts later in the storm. These structural features persisted during the sun-earth passage despite the large velocity dispersion.

Although the modulation of galactic cosmic rays in this storm, while appreciable, was in no way exceptional when compared with other Forbush-type decreases, the storm was nevertheless unique with respect to the great intensity of the associated ionospheric phenomena; this may reasonably be attributed to an exceptionally high density of the solar gas enveloping the earth. The aurora of February 10–11 was one of the most intensely studied solar-terrestrial phenomena of the IGY.

COSMIC RAYS

The scheduling of the IGY for a period of maximum solar activity was of particular value to cosmic ray research. Appreciable advances were made in our understanding of cosmic rays and their causes, effects, and interrelationships with other phenomena (see fig. 5). A very interesting aspect was the relevance of cosmic rays to exploration of the geomagnetic field.

The beam of cosmic rays coming largely from the galaxy changed drastically between the last minimum of solar activity (1954) and the present maximum (1957–58). S. E. Forbush, studying μ-meson intensities, found that the results show an 11-year cycle of intensity variations which is roughly opposite in phase to that of sunspot numbers but lagging in phase by about 1 year. J. A. Simpson and his colleagues (University of Chicago) found a decrease of 25 percent in neutron intensity at Climax, Colo., between 1954–55 and the early part of 1958, with a more than two-fold decrease in this period for particles with energies of 1 Bev. or greater. H. V. Neher (California Institute of Technology) found that ionization at Thule, measured aboard balloons at 93,500 feet, was only half that of 1954 and that the number of primary particles was diminished by a factor of 4. J. R. Winckler and L. Peterson (University of Minnesota) studied vertical particle flux using balloons at northern geomagnetic latitudes between 51.2 and 64.2 degrees: above 33,000 feet the flux decreased near sunspot maximum; the decrease becomes greater with increasing height and at both high latitudes and altitudes, was down by nearly a factor of two. These experiments showed that, of the additional particles admitted at some 100,000 feet in 1955 between north geomagnetic latitudes 51.2 and 58.6 degrees, at most only one-sixth remained near sunspot maximum and that the relative latitude effect in this range was reduced from 40 to 10 percent or less.

During the past several years, it has become clear through the work of U.S. investigators that the intensity of the cosmic radiation reaching the earth undergoes large changes with time, and that these changes are associated with electromagnetic phenomena on the sun. Phenomena that produce large changes in the cosmic ray intensity at the earth have become the central problem of interest. Not only does their study add to an understanding of cosmic ray and solar effects, but analysis of these data is leading to knowledge of magnetic fields in interplanetary space and to explanation of many magnetic storm effects at the earth's surface.

In 1957, large decreases in cosmic-ray intensity during magnetic storms were unusually numerous. Several U.S. investigators have recorded large variations in daily mean neutron intensity for various intervals during the IGY. The sudden decrease in daily mean neutron intensity from August 29–30, 1957, was between 8 and 10 percent at IGY stations operated by the Universities of California and Chicago and the Bartol Research Foundation (Pennsylvania). This is about 2.5 times the change in ionization at Huancayo.

M. A. Pomerantz (Bartol Research Foundation) reports that values of daily means of neutron intensity at Thule (August 20, 1957, to March 31, 1958) correlate well with values obtained by D. C. Rose at Ottawa and Resolute, Canada. Using balloons on several days between August 21 and September 18, Pomerantz also measured the vertical quadruple-coincidence rate under 7.5 centimeters of lead at altitudes above the 28-gram-per-square-centimeter pressure level (80,000 feet). These results show a decrease of about 20 percent near September 1, 1957, as compared with August 20, 1957.

Two experiments conducted in 1958 with balloon-borne pulsed ionization chambers revealed that the fluxes of both heavy nuclei and high energy protons did not change at the same time when a decrease of 23 percent in the total intensity was recorded as indicated above. Taking the results of other investigators into account, as well, Pomerantz concludes that the current general reduction in the primary cosmic ray intensity is a consequence of a change in the cutoff rigidity only. He points out that a sharp cutoff of protons unaccompanied by a corresponding cutoff of heavy nuclei could be reconciled by ascribing the observed decrease in primary intensity to the action of a cutoff mechanism at the sun upon low energy cosmic rays of solar origin.

Twelve-hour neutron-intensity means at Chicago from July 22 to September 1957 reported by Peter Meyer (University of Chicago) showed a range of nearly 20 percent. Meyer has also conducted balloon flights in Canada on days when the neutron intensity at Chicago differed, from one to another of these days, by 12 percent. His purpose was to determine whether the change in proton and alpha-particle flux is different at these two locations. On the basis of these balloon flights conducted during 1957 and 1958, Meyer reported at a recent meeting of the American Physical Society in Chicago that in general the modulation mechanisms responsible for intensity variations in cosmic rays affect both alpha-particles and protons in the same manner so that the ratio of fluxes remains constant. However, the independent behavior of the alpha-particle flux, when compared with the proton flux, as observed on certain individual flights,

if real, may occur only at certain times, and perhaps only following Forbush decreases.

Because cosmic rays are deflected by magnetic fields, they may be thought of as probes to reveal the distribution and configuration of the magnetic field in the regions surrounding the earth. Investigations to locate the magnetic equator for cosmic rays are being carried out through multiple crossings of the equatorial region by ships and aircraft. These studies by J. A. Simpson (University of Chicago) and M. A. Pomerantz (Bartol Research Foundation) were mentioned in the earlier report (1).

K. A. Anderson (State University of Iowa) has reported unusual balloon observations taken at an atmospheric depth of 10 grams per square centimeter at Churchill on August 22, 1958, in which ionizing radiation appeared beginning at 1525 UT in time association with a great solar noise storm. The response of three balloon-borne detectors was not consistent with X-rays, high-energy gamma rays, or with electrons as a principal cause, but did correspond to protons with a kinetic energy of 170 Mev. From one previous balloon flight made from Churchill in 1957 there was strong evidence for the appearance of protons in the 100-Mev energy region during a period of high solar activity, but no further confirmation was obtained until the occurrence of the more recent event. The time scale and certain of the details of the event bore a strong resemblance to an X-ray shower observed on August 29–30, 1957, which suggests that the protons in the present event and the electrons, presumed to have given rise to the X-rays in the earlier event, are affected by a common mechanism. It was definitely established that the radiation present during the 1958 event was not associated with visible auroras, for sky conditions were excellent for observations. There was little if any magnetic disturbance present at the time.

GEOMAGNETISM

Some 200 magnetic observatories recorded magnetic-field vector components on a regular basis during the IGY. These data, calling for appreciable analysis, have as their principal value their utility in interdisciplinary studies, particularly in correlations of events involving solar, ionospheric, auroral, and cosmic ray effects. Studies of cosmic rays themselves proved most revealing in throwing light on the earth's magnetic field in space. Emphasis in the United States geomagnetic effort was also placed on rapid variations, close network studies, and the electrojet phenomenon.

To determine whether magnetic field variations other than the daily variation also show electrojet effects, four stations equipped with Askania variographs were established for the IGY on the west coast of Peru by S. E. Forbush (Carnegie Institution of Washington), in cooperation with the Instituto de Geofisico de Huancayo. The maximum daily variation of the horizontal component was found to occur within 1 degree of latitude of Huancayo (12° S). This is in accord with results from the 1949 survey. It is also confirmed by the fact that the daily variation of the vertical component of the earth's magnetic field, obtained during the 1957 survey, changes sign at a latitude within 1 degree of Huancayo. A maximum daily variation in the vertical component occurred at about 16° S, and another maximum, with opposite sign, occurred near 8° or 9° S.

The north-south distance of 500 miles between these extremes provides a rough estimate of the width of the electrojet band. The difference with latitude of the daily variation of the vertical component indicates the importance of the return currents, which must flow westward, to the north and south of the eastward-flowing electrojet.

To estimate reliably the height and width of the electrojet, the electric current system of the electrojet field must first be derived. Before this derivation can be accomplished, the normal, quiet-day solar variation, estimated from data obtained at locations free from the influence of the electrojet, must be subtracted. Such height and width estimates have not yet been completed.

A preliminary examination of records indicates that many of the vertical-component fluctuations related to solar disturbances are greatest at the same latitudes where the largest quiet-day solar tidal variation in this component was observed. The sign of the fluctuations is opposite at these two latitudes, indicating electrojet effects.

A network of stations was established by E. Maple (Geophysics Research Directorate) to study geomagnetic fluctuations in the frequency range of 1 to 50 cycles per second. Maple has found that oscillations or micropulsations may

appear, as well as signals of varying frequency. The latter often resemble the whistlers of audiofrequency range. However, these subaudio "whistlers" sometimes first decrease in frequency and then increase, a behavior at odds with current whistler theory. Some correlations have been observed with magnetic activity, as well as occasional predisturbance signals.

The early data from the large network of IGY magnetic stations is under study and analysis by scientists at many institutions. The U.S. Coast and Geodetic Surveys reports that operation of the stations, even in difficult and remote areas has been satisfactory, and data are being received and reduced at the survey.

IONOSPHERIC PHYSICS

Because solar radiation largely determines the nature of the ionosphere, the character of the ionosphere close to the geographic poles during periods of prolonged solar absence was a subject of considerable interest. The South Pole station provided a unique facility for this study by the National Bureau of Standards because there Antarctica offered a stable platform in contrast to the uncertainties of the shifting ice pack in the Arctic basin. In these regions the ionosphere is subjected to extended exposure to solar ionizing radiations during the long polar summer day, while it is screened for several months during the polar night. Scientists of NBS, Boulder Laboratories, reported that, from analysis of South Pole records at hand, the ionization reached a summer saturation, during the present solar activity, of about 4.5×10^5 electrons per cubic centimeter, which would support transpolar communications up to 22 megacycles per second. Throughout the winter polar night, it was found that the F-layer persists but that this usually rather uniform layer appeared to break up into cloud formations. A density of 2×10^5 electrons per cubic centimeter appears typical, sufficient to support transpolar communications up to 14 megacycles in the absence of ionospheric storms.

There is evidence from the data from both polar regions that the nonsolar variations in the F-layer depend upon the magnetic dip field rather than the geomagnetic field. Analyses of data from the worldwide chain of ionospheric stations are under way to determine the source of these polar ions: Do electronic clouds drift from sunlit regions toward the South Pole or do they manage to persist somehow throughout the winter? It is interesting that the ionization exhibits diurnal variation even though the sun is always at a constant height above or below the horizon.

Backscatter studies, conducted over a network of 13 stations supervised by A. M. Peterson (Stanford University), were directed at two types of problems: those requiring reflections continuously from large regions and those where reflection geometry requires the backscatter oblique-incidence technique. This work permitted the study of large-scale F-layer traveling disturbances and studies of ionospheric tilts. Peterson reports that the former were tracked over several thousand kilometers, and it has been found that the disturbances often extend several thousand kilometers in directions perpendicular to their paths, appearing as huge wave motions in the ionosphere.

Analysis of backscatter data shows that tilts in the F-region permit radio wave propagation over great distances without ground reflections. Tilts or horizontal gradients permit the propagation of radio waves over long distances by successive reflections from the curved F-layer until a particular tilt directs the energy to earth. Propagation over distances in excess of 6,000 miles has been observed frequently.

During the IGY an extensive whistler program has been conducted by R. A. Helliwell (Stanford University) and M. G. Morgan (Dartmouth College) who are supervising two chains of stations running north and south along the coasts of North America, including cooperating stations in the Southern Hemisphere. Some of these stations were in operation prior to the beginning of the IGY, and it was at one of them (Hanover, N.H.) that correlation of whistlers and lightning flashes by direct visual and aural observations was definitely made just prior to the IGY. This has recently been reported in the literature with the conclusion that lightning flashes can generate whistlers although many of them do not.

The IGY whistler data show a marked dependence of the frequency of occurrence from place to place. Morgan finds that activity increases northward from none at all at Huancayo up to Hanover where a variety of very-low-frequency phenomena are recorded, and then diminishes nearly to the vanishing point at Frobisher Bay, North West Territories, and Thule, Greenland; high activity is noted from the Ellsworth Station in Antarctica. It is interesting that the

Hanover Station has far more activity than does Seattle, Wash., although the two are comparable geomagnetic latitudes.

Helliwell observes that high activity is also found at Unalaska, Alaska, and that in Alaska short whistlers are predominant whereas on the east coast of the United States short whistlers are a relative rarity. On one occasion the same whistler group was recorded at both Stanford and Seattle. However, the first component of the whistler observed at Stanford was extremely well defined and extended upward to 35 kilocycles per second, whereas no trace of the first component could be found at Seattle. Later traces in the group, on the other hand, were identical with those at Stanford. Nose whistlers (in which the frequencies both rise and fall simultaneously) have been observed for the first time at Stanford, and two have been found with nose frequencies of 10 and 16 kilocycles per second, which are low compared with the expected value of 45 kilocycles per second. A whistler has been recorded simultaneously at Stanford, Seattle, and Anchorage, even though the distance between Anchorage and Stanford is about 3,200 kilometers. The spectrograms show considerable similarity, but the dispersions of the separate components are not exactly the same at the three locations.

E. K. Smith (Central Radio Propagation Laboratory, National Bureau of Standards) has reported a peculiar signal enhancement noted during the last year on a very high frequency (49.84 megacycles per second) circuit operating between the Philippines and Okinawa which was set up to measure sporadic-E. The anomaly observed was a sudden enhancement of signal strength commencing about 2 hours after sunset and continuing until about midnight, being particularly strong during the autumnal equinox. This appears definitely to arise from F-region scatter. Studies by means of a pulse experiment carried out on the circuit seem to indicate F-region reflection from the path midpoint at 300 kilometers. The returned echo appears similar to those returned from extensive aurora curtains and may represent blobs of ionization oriented along the earth's magnetic field.

The reduction of vertical incidence ionospheric sounding records, or ionograms, to profiles of electron density as a function of true height, is being carried out at Pennsylvania State University by E. R. Schmerling, where an extension is used of the matrix method developed by Budden. Records from Washington, D.C., Panama, and Talara and Huancayo, Peru, have been reduced to individual profiles and read off to give the density at every 20 kilometers of true height. From examination of the 1957 data it has been discovered that the shape of the F-2 layer rarely corresponds to a parabola, an approximation sometimes used previously, and that there is a striking increase in electron density at night, particularly at Huancayo and Panama, where the layers rise at night and decrease in thickness.

Reduction of electron density profiles for many stations at scattered intervals (rather than more comprehensive coverage at a few stations) has been carried out at the National Bureau of Standards, Central Radio Propagation Laboratory, Boulder, Colo., by the same method to determine the instantaneous horizontal distribution of electron density at a series of fixed heights over the United States. Applications include the interpretation of radio data from satellites or other sources within or beyond the ionosphere, the determination of ray paths for radio waves reflected at oblique incidence from the ionosphere, the study of regional anomalies, and the study of large traveling disturbances.

Other ionospheric scatter effects are being studied in a cooperative program under the supervision of K. L. Bowles and R. S. Cohen (Central Radio Propagation Laboratory, National Bureau of Standards), with the South American participating committees of Argentina, Brazil, Chile, Ecuador, and Peru. Six circuits, in which transmission is affected by ionospheric scatter of obliquely incident 50 megacycle waves, have been established by the Central Radio Propagation Laboratory to span the geomagnetic equator and provide east-west control data. The variability in daytime scattering along these paths has been found to correlate with the presence of equatorial sporadic-E. There is further correlation with intensity variations of the horizontal component of the earth's magnetic field. Since these are in turn associated with the equatorial electrojet, these propagation studies are helping to define the relation between equatorial sporadic-E ionization and the equatorial electrojet. On the other hand, nighttime scatter signal seems to be correlated with the presence of disturbed conditions in the F-region observed as equatorial spread. The knowledge that the nighttime transmission scattering probably occurs at 130- to 180-kilometer levels suggests that some of the spread-F and some of the long-path scatter signals at

night are caused by the same ionospheric irregularities in the region from 130 to 180 kilometers in height.

ROCKETS AND SATELLITES

While rockets and satellites are only tools, albeit powerful ones, for in situ studies of phenomena in the high atmosphere and space, they have represented an important area of IGY activity and have stood in the international program as distinct efforts. Seven nations engaged in rocketry studies (Australia, Canada, France, Great Britain, Japan, the United States, and the U.S.S.R.) while two (U.S. and U.S.S.R.) launched satellites. More than 300 research sounding rockets of various types were fired, seven satellites were launched successfully, and one deep-space probe (Pioneer I) covered some one-third the distance toward the moon.

The quantity of data gathered by research sounding rockets was appreciable. Of great general interest were the studies of X-rays discovered by H. Friedman and his associates (Naval Research Laboratory) at times of solar flares in the lower, D-region of the ionosphere. It now appears this X-radiation creates the increased ionization which leads to radio-communications blackouts at times of solar activity. X-rays, Friedman reports, increase with solar flare activity, while ultraviolet radiation does not, although measurements have not been made during the initial period of onset of flares. Moreover, during the eclipse of last October, Friedman employed rockets for the first time in such a study (see fig. 6) and detected X-rays during total eclipse while ultraviolet radiation was completely absent, giving the first direct evidence that X-rays originate in the sun's corona, whereas ultraviolet radiation was absent during total eclipse. These experiments are significant not only because they add to our fundamental knowledge of the upper atmosphere and solar processes, but because the information sheds light on problems of the radio propagation.

Extremely important ambient pressure, temperature, wind and density data were also obtained from rocket firings by groups at the Naval Research Laboratory, Geophysics Research Directorate, University of Michigan, and the Army Signal Research and Development Laboratory. One of the significant findings revealed that the distribution of atmospheric pressure and temperature at high latitudes differs from that at lower latitudes. The density of the atmosphere is under strong solar influence. There appear to be latitude, seasonal, and diurnal effects. These effects appear only at high altitudes above Fort Churchill, while none of these effects appear at lower latitudes.

A program at the State University of Iowa using balloon-borne rockets, called rockoons, had as its major purpose the measurement of total cosmic ray intensity over a wide range of geographic and geomagnetic latitudes during the present period of high solar activity. Special points of interest are (i) comparison of the intensity at upper atmosphere levels in high southern latitudes with intensity at high northern latitudes, and (ii) investigation of the location of the latitude "knee" in the Southern Hemisphere. Van Allen and his colleagues at Iowa report that flight data which have been read and reduced to date indicate that the total cosmic ray intensity at upper atmosphere levels in high southern latitudes is within 5 percent of that in high northern latitudes, and about 4.3 times as great as that near the equator. They also show that during the present period of high solar activity the latitude knee is found at a latitude lower than 50° S. Cosmic ray intensity at various altitudes is being systematically plotted against geomagnetic latitude.

Another aim of the Iowa research rocket program was precise measurement of the intensity of the terrestrial magnetic field to altitudes over 75 miles in the region of the equatorial electrojet. Van Allen obtained four satisfactory sets of data on magnetic intensity in the Line Islands at altitudes up to 84 miles, and flight data reduced during the IGY indicate new evidence for the existence of electric currents in the lower ionosphere. The full reduction of all four sets of flight data obtained in the Line Island area, when combined with the ground station measurements, is expected to yield illuminating information on the equatorial electrojet.

Several other Iowa experiments were conducted in the southern auroral zone. High-altitude measurements of the magnetic field were made for correlation with nearby antarctic observations. There were three successful magnetometer flights. Investigations were made here of the physical nature, intensity, and latitude distribution of the "soft radiation" associated with auroras. A flight at 70°48′ S., 175° 50′ E., was the only successful rocket flight of auroral instrumentation made in the zone. It encountered a high intensity of soft radiation resem-

bling that studied extensively in the northern auroral zone during the rockoon expeditions from 1953 to 1957.

The most significant on-board satellite experiment to date now appears to be the work of Van Allen and his associates at the State University of Iowa, with radiation instrumentation on satellites 1958 alpha, gamma, and epsilon (commonly referred to as the Explorer satellites) (see fig. 7). Satellite 1958 alpha led to the discovery of a zone of radiation in the high atmosphere. Van Allen reported that data from 1958 alpha and beta indicated that the radiation intensity of cosmic rays to 700 kilometers was as expected, but instrumental behavior beyond this range pointed to a great increase in intensity totally inconsistent with cosmic ray expectations. The radiation was interpreted as corpuscular in nature.

More sophisticated instrumentation on 1958 epsilon provided added and better information. Van Allen and his colleagues believe it is established that the great radiation belt around the earth consists of charged particles, temporarily trapped in the earth's magnetic field." They conjecture that the aurora is related to this trapped radiation and is caused by particle leakage from the belt. They suggest that solar plasma is the source of particles. These studies, in combination with other results of the IGY (the cosmic ray work, in particular), begin to relate a variety of atmospheric and spatial phenomena in an exciting and meaningful way, suggesting that major advances are in process of being made and formulated.

Many environmental studies were also carried out such as the temperatures of satellites (internal and skin) and exposure and behavior under micrometeorite bombardment. The solar batteries carried on 1958 beta have continued to operate since launching and have proved the feasibility of this source of power.

REFERENCES AND NOTES

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2. The preparation of this summary of IGY is based entirely upon reports and descriptions of projects supplied by the scientists and institutions engaged in the IGY research program. Many of them are mentioned in the text, although in this short summary it has not been possible to refer to all of the scientists who are producing contributions through their IGY programs or to describe all of the IGY accomplishments. The U.S. IGY program itself has only been made possible through the great contributions of time and effort of so many individual scientists and the participation and cooperation of public and private institutions. Particular acknowledgement should be made to members of the National Academy of Sciences' IGY staff who have assisted in the collection and preparation of the material contained in this article, Phillip W. Mange and Stanley Ruttenberg.

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International Geophysical Year

(The second part of a two-part summary of IGY activities covers heat and water, the earth, and data exchange)

(By Hugh Odishaw[1])

The first part of this article (1) outlined the scope of the IGY effort and attempted to summarize some aspects of the work dealing with the physics of the upper atmosphere, including solar and interplanetary medium relationships.

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This second part (2), also drawn from reports of the IGY scientific community and illustrative of their activities, takes up the story of typical findings in the areas of the heat and water regimen (meteorology, oceanography, and glaciology) and of the earth sciences (seismology, gravity, and longitude and latitude determinations). It also summarizes the status of data flow, for the IGY was above all a synoptic data effort, and then takes a look at post-IGY programs growing out of the IGY.

HEAT AND WATER

Just as studies of particles, radiations, and fields benefited during the IGY from its concerted studies in a half a dozen fields of science, the opportunity for simultaneous investigations in oceanography, glaciology, and meteorology brought with it possibilities of better understanding of the complex of heat and water. While the three chains of pole-to-pole meteorological stations yielded the raw data from which major atmospheric circulation patterns can be devised, some 80 oceanographic vessels provided data of various kinds for delineation of oceanic circulation systems. Carbon dioxide was measured in atmosphere and ocean. Sea-level measurements, humidity determinations, and snow and ice estimates all tie into establishment of the role of water in all three of these states, relating inevitably to the heat budget and currents.

Meteorology.—To explore more completely atmospheric circulation patterns, the IGY upper-air sounding program was characterized by two major efforts: (*i*) The filling in of major geographic gaps in the world networks, particularly in and near Antarctica, and (*ii*) the extension in altitude of balloon soundings up to about 100,000 feet.

Prior to the IGY emphasis on higher soundings, routine 600-gram balloon flights averaged about 71,000 feet. It should be noted, however, that the U.S. Weather Bureau and the balloon manufacturers have engaged in a continuing program to improve balloon performance, and that during the IGY an improved 600-gram balloon was used at all stations for the 0000Z observations and at one-third of the stations for the 1200Z observations. In pre-IGY tests, 80 percent of the 600-gram balloons had an average burst altitude of 82,020 feet, with a highest altitude of 99,670 feet. A high-performance 800-gram balloon was used at two-thirds of the stations for the 1200Z observations (chosen because this is the observation used for preparation of the IGY world weather maps); 24 of these balloons tested at the beginning of the IGY had an average burst altitude of 107,180 feet. During the IGY the 600-gram balloons have performed well, with average burst altitudes of about 83,000 feet; average altitude attained with the 800-gram balloons was about 90,000 feet. This program has achieved its objectives well enough to allow routine preparation of 10-millibar maps for stratosphere circulation studies.

Much was learned about antarctic weather; this is the first time such data have been collected to any appreciable extent. The coldest part of our planet is not at the South Pole but some 400 miles away, toward Australia, at the U.S.S.R. IGY Vostok station located at 106°52′ E., 78°27′ S. Near there, Soviet scientists recorded a low of −124° F. on August 17, 1958. The South Pole station was the coldest of the United States–IGY stations, with a minimum of −102.1° and an annual average of −56° F. Byrd station recorded a low of −82°, a maximum of +24°, and an average of −18° F.; wind averaged 20 knots from the northeast, with maximum of 83°. The many overcast days during the winter contributed to making the weather environment there the worst of that at any of our stations.

The weather of Little America and Ellsworth stations was similar to that at the South Pole station but somewhat warmer, while at the Wilkes station the lowest temperature was −27° F. U.S. Weather Bureau scientists at Little America report a 5° rise in annual mean temperature there over about 50 years—about one-half that noted at Spitzbergen in the Arctic—confirming a belief in the warming trend of the last few decades.

Beyond the extensive measurements of temperature, pressure, wind speed and direction, humidity, precipitation, and so on, made in programs conducted synoptically around the world, the IGY program embraced special studies. Thus, the U.S. program included research in solar radiation, ozone, carbon dioxide, and natural and artificial atmospheric radioactivity (see fig. 1). Special solar radiation studies were conducted at seven antarctic stations (fig. 2), at the two ice stations in the Arctic Basin, and on Mauna Loa, T.H. Measurements were made of the intensity of total solar and sky radiation on a horizontal surface, intensity of the direct solar beam, natural illuminations, surface, albedo, and hemispherical and net radiation.

The large amount of data stemming from this work is being reduced and processed. One of the observations at hand has to do with atmospheric purity: It turns out that the purities at Little America and Mauna Loa are comparable, while at the South Pole the sky is even clearer. Preliminary results from Station Alpha in the Arctic indicate the great importance of long-wave radiation from overcast skies in melting, for melting proceeded much more rapidly under overcast skies than beneath clear skies and in bright sunshine; conversely, refreezing may occur under clear summer skies because of increased outgoing radiation.

At Little America station, both surface concentrations and total ozone were measured. U.S. Weather Bureau scientists have analyzed some of the data (figs. 3 and 4). They point out that the data are yet tentative, subject to further calibration of the equipment. Total ozone was observed with a Dobson ozone spectrophotometer, while the surface values were obtained with equipment developed by V. Regener (University of New Mexico) which employs the potassium-iodide–sodium-thiosulfate method with electrolytic titration.

During the winter months, the total ozone averages shown in figure 3 were based on two to four measurements taken on the full moon; averages for the remaining months are based only on measurements taken on the direct sun.

A marked feature of the annual variation in surface ozone (fig. 4) is the rapid rise of ozone in March and April, when the sun leaves, and the slow decrease beginning in September after the sun returns. The dependency of surface ozone on wind direction is shown in figure 5, for June 1957. The "ozone rose" is drawn in terms of deviation in percentage from the average monthly concentration of 64 micrograms per cubic meter of air.

The usual diurnal variation of surface ozone concentration found at middle-latitude stations shows an ozone maximum during the late morning or early afternoon with a minimum during the late evening or early morning hours. This variation is believed to be due to the change of the vertical "Austausch" during the day. Afternoon convection activity permits the ozone to be carried down from the upper layers, but during the evening the lower air layers become stratified and the downward transport weakens. Eventually the surface ozone is destroyed more rapidly than it can be replaced from above, and the concentration may drop almost to zero. At mountain stations this diurnal variation may be wholly absent or it may be influenced by the diurnal variation of the mountain-valley wind.

The hourly values of ozone concentration for Little America are presently available only for the months of April to November 1957, inclusive. The results of a harmonic analysis of this data are shown in table 1.

The diurnal variation found at Little America differs markedly from diurnal variations reported at middle-latitude stations. During the winter months the maximum occurs during the early morning, at about 0300 hours (165th meridian time), but during the spring it shifts to 0600 hours. The amplitude of the variation is rather uniform during the winter but increases by a factor of three in September and then decreases again during the spring.

As a result of the IGY, daily weather maps of the entire globe will be prepared; the United States is assigned responsibility for the Northern Hemisphere; South Africa, for the Southern Hemisphere; and the German Weather Service, for the equatorial belt. Daily maps at two levels—sea level and 500 millibars—will be prepared. It is expected that the IGY world weather maps will be available after an interval of 1 or 2 years.

Oceanography.—Two major objectives of the oceanographic program were the study of the sea-level changes and oceanic water budget and the study of water masses, particularly current systems. In addition, of course, much related work was including during the IGY cruises—for example, bathymetry, marine geological investigations, biological work, and geochemical investigations. For the study of the water budget, more than 350 tide gage stations were operated by 25 nations. In addition to tide observations, instruments were installed at some stations to record the long-period ocean waves, variations in atmospheric pressure, and continuous records of air temperature. At as many locations as possible, the temperature of water to depths of 900 feet was measured with bathythermographs (fig. 6), and water samples were taken for chemical analysis. These observations were designed to permit volumetric corrections to be applied to the observed sea-level fluctuations in order to obtain the true mass fluctuations.

About 80 research vessels, of 20 countries, participated in the cruise part of the program. Many expeditions which involved direct cooperative participation

by ships of several countries were conducted; for other parts of the program, oceanographers agreed among themselves on the timing and tracks of cruises to yield synoptic and adequate spatial coverage of the ocean masses under investigation.

An earlier article on the IGY (3) described the discovery of the current beneath and opposite the Gulf Stream, in an early cruise sponsored by the Woods Hole Oceanographic Institution and the National Institute of Oceanography, England, and mentioned other early IGY results. The Scripps Institution of Oceanography finished three IGY cruises, the first of which was briefly described in the same article (3). The other two cruises were planned to study the equatorial undercurrent and countercurrent in the eastern Pacific. J. A. Knauss reports that the undercurrent, first investigated in 1954, is centered at the Equator and is at least 3,500 miles long, with a transport of the order of 30×10^6 cubic meters per second. The highest velocities observed were at depths of 100 to 113 meters and were between 2 and 3½ knots. The Scripps research vessel *Horizon* and the *Hugh M. Smith* of the Pacific Oceanic Fisheries Investigation participated in the second Scripps Institution of Oceanography-IGY cruise, called Dolphin.

In the third Scripps cruise, Doldrums, Knauss found that the Pacific Equatorial Countercurrent was far more extensive than had been suspected earlier on the basis of calculations of the geostrophic current. The direct-current observations employed in the IGY cruise showed that the countercurrent extends below the thermocline and actually transports more water below the thermocline than above it; the total transport was found to be about 50×10^6 cubic meters per second.

The measured eastward transport in the equatorial Pacific is estimated to be at least three times that estimated earlier by Sverdrup. This calls for a renewed investigation of the water balance and mass transport in the equatorial Pacific.

Much information on water mass and currents will be obtained not only by means of the direct methods (Swallow float, parachute drogues, current wheels, anchored buoys, and so on) but also from the study of temperature distribution, concentrations and distribution of the various chemical solutes, and radioisotopes. Analysis of cores of bottom sediments will provide clues to past circulation patterns. For example, sediment cores collected in the Arctic Basin before the IGY, at ice island T-3, and in the Atlantic provided information leading to a recently developed theory of glacier fluctuations by M. W. Ewing and W. Donn, of the Lamont Geological Observatory.

Significant contributions to knowledge of marine topography resulted from the bathymetry undertaken on IGY cruises and also from observations from the drifting ice stations in the Arctic Basin. R. L. Fisher and H. W. Menard, of the Scripps Institution of Oceanography, have reported on their exploration (during the first Scripps Institution of Oceanography-IGY cruise, Downwind) of Nasca Ridge, a submarine mountain range extending southwest from just outside the Peru-Chile Trench off central Peru for a distance of at least 600 and possibly 1,000 miles. Nasca Ridge was known previously only from several spot shoal soundings and a few echo-sounding crossings. Seismic refractions, heat-flow measurements, dredging, and coring completed the exploration of the ridge.

The Peru-Chile Trench was extensively explored, and heat-flow measurements were made near the trench, in the basin to the west, and in the Tuomotu Archipelago and East Pacific rise. All told, 32 successful heat-flow observations were made—more than had been made previously. R. R. Revelle and R. Van Herzen reported that the highest values, 3 to 7×10^{-6} calories per square centimeter, were observed on the East Pacific rise. An indication was obtained of a trend toward much lower values near the axis of the Peru-Chile Trench, to the east. The study of these values of heat flow, particularly in relation to the topography, promises to advance the understanding of the structure of the general area.

Extensive areas were discovered where there existed a sludge containing manganese, iron, cobalt, and copper, in concentrations suggesting an ore value of about $500,000 per square mile. Aside from the possible economic importance of these ores, the understanding of how these metals are concentrated, probably by biological processes, will bear on our understanding of the geochemistry of the oceans.

In the Arctic Basin, Lamont scientists on station A discovered a submarine ridge parallel to the Lomonsov Ridge and lying about 85° N. in the vicinity of

166° to 168° W. The ridge is about 5,000 to 6,000 feet high; the full linear extent (at least 50 miles) is not yet known.

The Woods Hole vessels *Atlantis* and *Crawford* completed exploration of additional sections in the Atlantic Ocean, providing a coverage during the IGY more extensive than ever before. Woods Hole scientists have also engaged in a comprehensive geochemical program, and water samples have been secured for analysis H^3, C^{14}, Sr^{90}, Sb^{125}, Cs^{137}, Ce^{144}, and Pm^{147}.

The *Vema* (see figs. 7 and 8) of the Lamont Geological Observatory completed a 10-month IGY cruise. The two-ship seismic profiles were an important features of the work; these were made in cooperation with *Atlantis* in the Red Sea. Lamont scientists have also taken many large-volume water samples for C^{14} and H^3 analysis. The *Hidalgo* of the Agricultural and Mechanical College of Texas completed a 60-day cruise in the Gulf of Mexico and Caribbean Sea, for study of currents. The *Brown Bear* of the University of Washington completed a second IGY cruise in the Northwest Pacific, where anomalous warm-water masses were studied, deepwater samples were collected in the Aleutian Trench, and studies were made of water exchange between the Bering Sea and the Pacific Ocean.

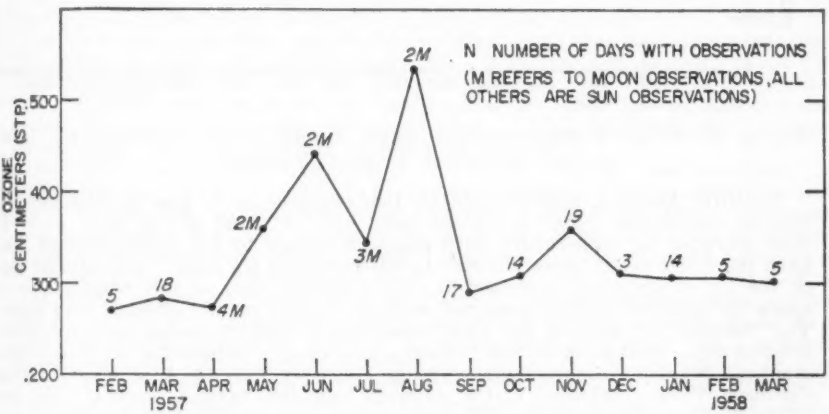

FIGURE 3.—Mean monthly total ozone values, Little America V (78°S.; 162°W.) [U.S. Weather Bureau]

U.S. Navy Task Force 43 vessels in the Antarctic were able to make several crossings of the Antarctic convergence, taking bathythermograms and water samples. About 190 oceanographic stations have been obtained since the pre-IGY exploratory cruise of the *Atka*. In addition, at Little America and near Hut Point, McMurdo Sound, stations were reoccupied over a period of months. Both at Little America and at Hut Point there was observed a rapid summer decrease in salinity, reflecting melting of pack and shelf ice, with warming confined to the upper layers. In autumn, temperatures rapidly reverted to spring values but salinity responded more slowly.

Glaciology.—Glaciers are among the most sensitive climatic indicators in nature. Past climates and climate fluctuations can be read from the snow and ice strata deposited from year to year, and annual variations in accumulation or shrinkage and in advances or retreats of the ice front provide keys to past and current climatic trends. During the IGY, glaciologists of 28 countries are making observations covering all the known ice areas of the world, including the great ice sheets of Greenland and Antarctica and a large number of valley glaciers in both polar and equatorial regions.

At the IGY Byrd Station in the Antarctic a deep drilling program reached a depth of 1,013 feet. Because of the relatively small annual accumulation of snow in the Antarctic, ice at 1,000 feet below the surface at Byrd Station is roughly equal in age to ice at the 2,000-foot level in Greenland. However, the Antarctic cores are more difficult to date. In Greenland, the annual layers of snow are generally marked by a thin crust of refrozen summer melt; in the Antarctic, the

annual layers are thinner and more closely packed, and there is often little or no summer melt. Careful chemical analysis may be needed to date the deep-lying cores, but it is estimated that the ice removed from the Byrd Station 1,000-foot drill hole fell as snow about the time of Charlemagne's birth.

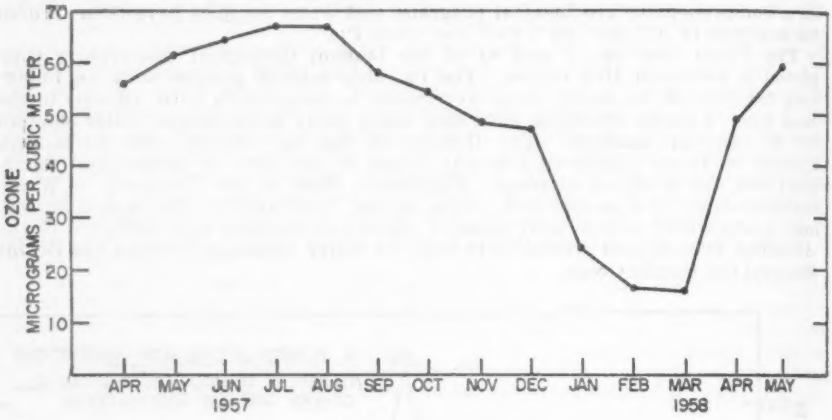

FIGURE 4.—Mean monthly surface ozone values, Little America V (78°S., 162° W.) [U.S. Weather Bureau].

At Little America, approximate ice temperatures at various depths were as follows: at 55 feet, —9.9° F.; at 85 feet, —8.7° F.; and at 130 feet, —8.0° F. This increase in temperature with depth is caused by the conduction of heat from the warm ocean below the 800- to 950-foot-thick ice shelf. The gain of heat at the top of the shelf, however, is only 1 percent that of the average loss to space by radiation and so does not serve to ameliorate the climate very much. The "barrier" or edge of the shelf near Little America moves seaward about 5 feet a day. Stakes have been located across two ice valleys for movement-rate studies. Precise measurements made in February 1958 by A. P. Crary across Crevasse Valley, between Little America and the barrier, showed that the 11,500-foot-long line laid out 375 days earlier had stretched 14 feet; this confirmed earlier observations showing that the valley is widening and that its underlying ice is becoming thinner.

TABLE 1.—*Harmonic parameters for diurnal ozone concentration variations for the year 1957 (U.S. Weather Bureau)*

Month	Amplitude ($\mu g/m^3$)	Time of maximum of the oscillation (hour after midnight)
April	2.7	2.0
May	.6	2.1
June	2.2	2.6
July	2.0	2.9
August	1.9	2.7
September	6.1	2.9
October	2.6	4.0
November	1.2	5.5

To study the properties of larger areas of the great Antarctic icecap as well as other phenomena, U.S.–IGY Antarctic scientists completed three major traverses which covered a total of over 4,000 miles out of the IGY Little America, Byrd, and Ellsworth stations.

The Ross Ice Shelf traverse from Little America covered a distance of 1,440 miles in 113 days. It found that the shelf thickness varies from 800 to 950 feet, near Little America, to 1,000 to 1,100 feet west of Roosevelt Island and gradually increases to 1,400 feet at the Beardmore Camp. The shelf floats but is grounded at Roosevelt Island and probably at other shallow areas. The ocean depth varies from 2,000 feet at Little America to 2,600 feet near Minna Bluff and then decreases south toward the Beardmore.

The Byrd traverse covered 1,180 miles from November 19, 1957, to February 20, 1958 (see fig. 9). It found that from the boundary of the Ross Ice Shelf to the Sentinel Mountains the underlying topography is alpine, with ice thickness varying between 2,000 and 9,000 feet. All but a few peaks of the rock floor are at present below sea level; the major portions are far enough below sea level to be under water even if the ice were removed and the land were allowed to rise, as it would without its great burden of ice. The second leg of the Byrd station traverse shows quite a different picture—a smooth bottom, great ice thickness of 7,500 to over 11,500 feet, and broad gravity anomales. The underlying rock along the final leg of the traverse, southwest and then west from the Sentinels, shows still another character. Surfaces there are very rough and mostly above sea level, in several places breaking the ice surface to form nunataks. One hundred miles each of Byrd station, ice 14,000 feet thick was found resting on a rockbed 8,200 feet below sea level. This is believed to be the thickest ice layer measured anywhere in the world.

The Ellsworth traverse investigated the Filchner Ice Shelf and the inland ice of Edith Ronne Land. In addition to making glaciological studies, the Ellsworth party investigated mountains and rock outcrops in and near its route of travel. And important goal of this traverse was to occupy a point that could be reached by the Byrd station traverse of 1958–59, thus providing a link across which data could be correlated. The traverse party traveled 1,250 miles in 81 days. The party deviated about 120 miles from the planned route to make geological studies and collect rock specimens at a newly discovered mountain range, at 82°30′S and between longitudes 50° and 54°W, which may be part of the Pensacola Range (fig. 10). Black stratified bands were noted high on the mountains, and a 5,000-foot escarpment was discovered on the southern side. Evidence of mineralization was present in the form of abundant green malachite stains. Some of the bright green stains were visible at 100 yards. Large ice-free areas also were found along the northern foot of the range. One of these dry valleys contained a fresh water lake about 100 yards in diameter, partly ice free, caused undoubtedly by melting of snow in contact with the dark ground, which heats rapidly in the brilliant sunshine. The lake contained abundant plantlife, and specimens were collected for botanical analysis.

A 2,500-foot-high, ice-covered island extending for about 230 miles south and west from Gould Bay was discovered. Seismic soundings near its eastern extreme showed the land surface beneath the island's ice mantle to be at about sea level. Other islands, whose contours were not fully delineated, were seen still farther westward. Under the ice shelf a deep trough was detected extending inland from the vicinity of the Belgrano station, located 35 miles east of Ellsworth station. The bottom of the trough averages 3,500 feet below sea level. After heading southward from Belgrano for some distance, the trough swings southwesterly, passing between the island and the newly discovered mountains. It continues beyond the southerly limits of the traverse.

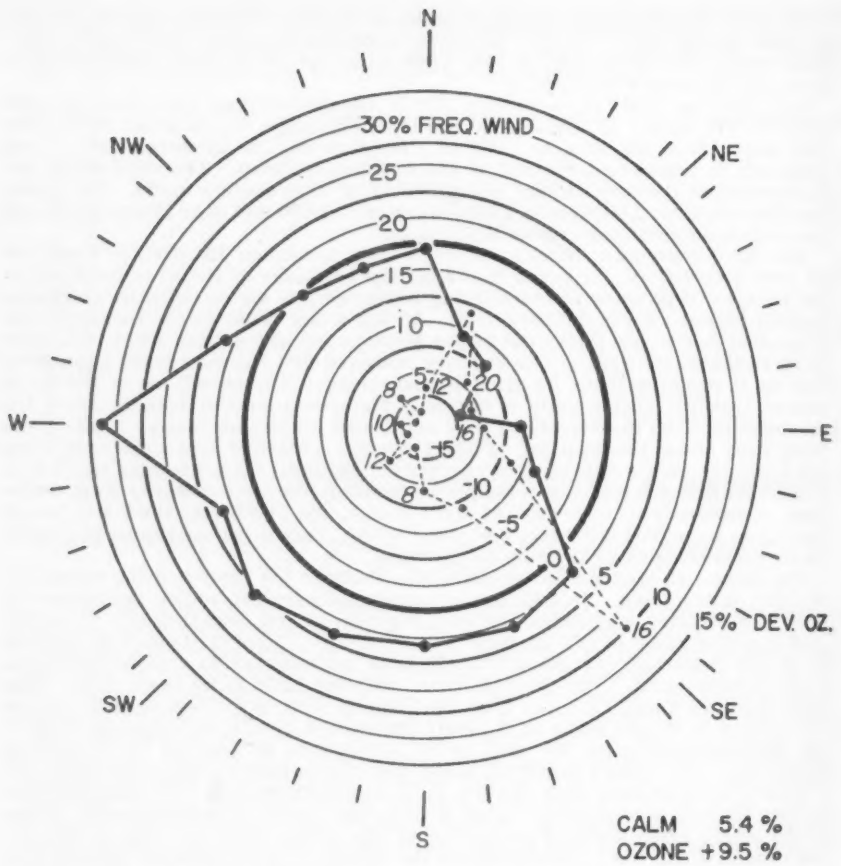

FIGURE 5.—Surface ozone and wind roses, Little America Station, June 1957. Solid line, surface ozone in percent of deviation from monthly average; broken line, wind direction frequency in percent; numerals, average wind speeds in knots (U.S. Weather Bureau).

The various determinations of ice thickness in Antarctica indicate that perhaps 40 percent more ice (or almost 4.5 by 10^6 cubic miles) is present than was estimated before.

An ice-deformation project, concerned mainly with the measurement and mapping of deformed ice features of the Ross Ice Shelf between Roosevelt Island and the Bay of Whales, also was undertaken, under the direction of J. A. Zumberge of the University of Michigan. Large-scale topographic maps were made of selected areas so that details of change in the shelf-ice surface could be recognized in future years. Zumberge reports that several deformational features were recognized during the studies: (i) ice anticlines produced by horizontal tensional stresses; (ii) the transverse crevasses lying across the anticlinal axes, produced by horizontal tensional stresses; and (iii) the products of shearing action. Thermal studies and meteorological observations were also made during the project.

The Pleistocene glacial chronology of the McMurdo Sound region was studied during the 1957–58 antarctic summer season by a two-man field party, led by Troy L. Péwé, of the University of Alaska. Péwé found, by examination of the glacial deposits in the region, that both the alpine and outlet glaciers have fluctuated widely in the geologic past. The two groups of glaciers are now independent, but in the past they merged to fill McMurdo Sound with ice. At several times in the latter part of the Pleistocene epoch many large lakes formed when valleys were blocked by glaciers or glacier moraines. These valleys are

now dry, but shorelines, deltas, lake clays, and evaporite deposits (mirabilite) remain to attest to the former existence and extent of these lakes. A comparison of the present positions of the fronts of many glaciers of the McMurdo Sound region with the positions of the same fronts shown in photographs taken 46 years ago reveals that very little or no change has taken place in this almost half-century interval. Adjacent to many alpine glaciers are small ice-cored lateral moraines about 100 feet high. These moraines are extremely fresh and may represent minute glacial advances of the last few centuries.

The glaciology program also includes an effort to determine the present pattern and magnitude of shrinkage or growth of glaciers in the United States. Two teams of scientists are studying the Blue Glacier situated in Olympic National Park (fig. 11). An important finding to date is the unexpectedly high precipitation in the area. E. LaChapelle of the University of Washington reports that, judging by records obtained during the first 6 months of the operations, it may well be that Mount Olympus is the wettest area in the continental Unied States. In January 1958, for example, snow accumulated on Blue Glacier to a depth of 120 inches, with a water equivalent of 30.44 inches, and by the end of February, 417 inches of new snow had fallen. R. A. Sharpe of the California Institute of Technology reports that seismic soundings indicated a maximum thickness of the glacier of 920 feet. Maximum surface movement was found to be about 5.9 inches per day.

Additional glaciological studies were carried out in other parts of the Western United States, principally at South Cascade Glacier in the Cascade Mountains, at Grinnell Glacier in Glacier National Park, at Nisqually Glacier in Mount Rainier National Park, and in other national parks, including Yosemite National Park. The McCall Glacier in the Brooks Range, the Lemon Glacier near Juneau, and parts of the Alaska Range were also studied by U.S. IGY glaciological teams.

EARTH SCIENCES

Seismology.—During the IGY, the United States undertook three major programs in seismology: study of the earth's crust, largely by means of explosion seismology on land and sea; study of the earth's interior by means of earthquake seismology, with special attention to new long-period seismometers; and measurements of the ice thickness in Antarctica by seismic traverse parties.

As part of the study of the earth's crust, M. A. Tuve and H. E. Tatel of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington undertook an expedition to the Andes in Chile and Peru. Large explosions (40 to 60 tons) used in copper mines were observed near Chuquicamata, Chile, and Toquepala, Peru. The indications are that the depth to the mantle in Peru in a region where the elevation averages 9,000 feet is about 34 kilometers, whereas in Chile, in a region where the average elevation is 5,000 feet, the depth to mantle is more nearly 55 kilometers. These findings are not in agreement with the simple theory of isostasy; however it has been suggested that the lofty mountains of Peru may be supported by a network of fine roots penetrating to great depth into the mantle. The work in the Andes served to strengthen the belief of the Carnegie group that the old concept of a broadly featureless and uniform upper region of the mantle is an oversimplification.

Crustal studies have also been carried out by the Wisconsin group under G. P. Woollard. In 1957, this group made seismic profiles in the Mexican plateau. Under average elevations of 5,000 feet, the depth to the Mohorovicic discontinuity was calculated to be about 40 kilometers. Detailed work near the shot point revealed two layers overlying the "normal" (6.1 kilometers-per-second) crustal layer: 1 kilometer of 3.3-kilometers-per-second and 5 kilometers of 5.1-kilometers-per-second crustal layer. In the summer of 1958, this group made seismic profiles along a gravity high (+10 mgal) on the Keweenaw Peninsula in Michigan, along a gravity low (—40 mgal) in northern Wisconsin, and in a region of zero anomaly in Arkansas. Woollard reports that the respective depths to the Mohorovicic discontinuity were found to be 35, 37, and 43 kilometers. As in the Mexican plateau, a layer with thickness of 1 to 2 kilometers and velocity of less than 5 kilometers per second was found in each of these three areas. The need for careful attention to such layers has been emphasized by Woollard, Press, and others.

As part of the oceanographic work of the Scripps Institution of Oceanography during the Expedition Downwind (October 21, 1957 to February 28, 1958), seismic refraction and reflection studies were made by R. W. Raitt and G. G. Shor. Among the findings of this group were the thinnest (4 kilometers) and thickest (15 kilometers) crustal sections ever measured in the Pacific. Careful work re-

vealed the presence of a layer of intermediate velocity (4 to 6 kilometers per second) between the sediments and the "normal" crustal layer.

Heat flow ranged over a factor of 50, demonstrating interesting correlations with seismic determination of crustal thickness. For example, on the east Pacific rise, where heat flow is greater than in most areas, the crust is thicker and the seismic velocity of the layer presumed to be the mantle is nearly 7.6 kilometers per second. These correlations are being studied at the present time. The vital role played by many phases of the oceanographic program of this expedition is worth noting. Temperature, salinity, depth of water, and heat-flow measurements are all essential to the reduction and understanding of seismic data.

Another part of the IGY program has been the installation of a worldwide network of a special long-period seismometer of a type recently developed at the Lamont Geological Observatory and the California Institute of Technology. These instruments have revealed the existence of important energy components in seismic waves with periods greater than 50 seconds. These long waves include surface waves with periods of 600 seconds and low-velocity waves with periods of 200 seconds, which are as yet unexplained.

Two extensometers, or strain seismometers, have been installed in South America (Chile and Peru) by Hugo Benioff of the California Institute of Technology. These instruments, capable of measuring a strain equivalent to a change in distance of one-tenth inch in 2,000 miles, also serve as long-period seismometers and, as such, have measured long-period waves from earthquakes and the longer period (12-hour) strains due to earth tides. The site chosen for the extensometers in Peru has proved to be an unusually quiet site for a seismometer.

Seismograph stations at four U.S. stations in Antarctica have provided the first seismic records from this area. Records from these stations, which fill a gap in the previous seismic network, will make it possible to confirm and modify existing time-travel curves for the Pacific region.

The Wilkes station, whose seismograph was installed under the guidance of Frank Press of the California Institute of Technology, has a very special locality. This station is so situated that it is diametrically across Antarctica from the tip of South America. The direct path from an earthquake in this area to Wilkes must therefore follow a transantarctic path. When such an earthquake of proper size has been recorded at Wilkes and when the records have been analyzed, it will be possible from the study of group velocities to determine whether the structure of Antarctica is essentially continental or oceanic—that is, whether Antarctica is a continent or an island group.

This same problem has been attacked by seismic traverse parties, whose work has revealed the antarctic ice sheet to be much thicker than had originally been supposed. Measurements made by seismic traverse parties in the antarctic summer of 1957–58 and in the pre-IGY period demonstrated that the rock underlying the ice sheet is considerably below sea level in many regions. The traverse party from Little America led by A. P. Crary provided new evidence that east and west Antarctica may be separated by a deep ice-filled trough, through the recent discovery of the greatest recorded depth to bottom beneath the Ross ice shelf—4,400 feet below sea level.

The existence of such a trough (from the Ross Sea to the Weddell Sea) was postulated by Griffith Taylor, geologist with the 1901–04 Scott expedition. His conclusion was based largely on the division of Antarctica into two distinct segments (east and west) on the basis of geologic and geographic character.

East Antarctica is a vast elevated shield of pre-Cambrian metamorphic and igneous rocks, overlain by a thick series of flat-lying sedimentary rocks, intruded in places by igneous materials. West Antarctica is characterized primarily by folded ranges and plateaus of metamorphic rock and igneous intrusions similar to those of the Andes. These are also overlain by younger sediments. The existence of this trough is also suggested by the deep penetration into Antarctica of the Ross and Weddell Seas.

Further work is in progress during the present antarctic summer to determine whether the trough extends all the way to the deep basin discovered earlier in Marie Byrd Land and from there to the Ross Sea. An IGY Byrd station traverse, led by Charles Bentley, is now en route to the Horlick Mountains, which extend southeastward from the southeast corner of the Ross ice shelf; this group is making geophysical studies that are expected to help solve the problem of the trough's existence and exact location. An IGY airborne traverse led by Edward Thiel has launched a series of seismic and gravity measurements in Marie Byrd Land to seek further evidence as to whether the ice-filled basin

found there by members of the 1957–58 Byrd station traverse may be part of the hypothetical trough connecting the Ross and Weddell Seas.

Gravity.—The IGY program in gravimetry was designed to provide standards for calibration of gravimeters and for international datum control. Four meridional lines were established by the group led by G. P. Woollard of the University of Wisconsin: Alaska to Chile, Greenland to Argentina, Norway to South Africa, and Japan to Antarctica. These measurements were made by means of gulf compound quartz pendulums. For comparison of possible systematic difference, some of these stations were also measured with the Cambridge compound Invar pendulum.

Gravimeter measurements were made in conjunction with seismic observations (but more frequently than the latter) by the Ellsworth, Byrd, and Little America traverse parties. In addition, the British Trans-Antarctic Expedition, led by Sir Vivian Fuchs, made gravity observations at approximately 10-mile intervals along its entire route (using a gravimeter loaned by Woollard).

The first successful measurements of gravity on the surface of the open sea were made on November 22, 1957, by J. Lamar Worzel, of Lamont Geological Observatory, using the recently developed Graf sea gravimeter. This instrument overcomes the principal difficulties previously encountered in making gravity measurements at sea: (i) Nonavailability of the submarines that were required for this work, and (ii) poor determinations of position by a submerged submarine.

The new sea gravimeter was found to have additional advantages over the standard submarine pendulums. Surface gravity measurements made by Worzel from a stabilized platform aboard the U.S.S. *Compass Island* were taken in 9 hours, as compared with 2 days required for earlier submarine measurements of comparable areas. The data were reduced in just one-half day, as compared with 2 weeks needed to adjust and compute data from the submarine measurements. Two sea gravimeters are now in operation at Lamont. In a relatively short time it will be possible to cover the oceans with an impressive network of gravity profiles.

L. B. Slichter, of the University of California (Los Angeles), has directed the U.S. program for measuring earth tides by special gravimeters sensitive to changes in gravity of one part (or less) per billion. Recordings have been made by 2 such instruments at 13 sites: Glendora (California), Honolulu, Wake Island, Baguio City (Philippines), Saigon, New Delhi, Bermuda, the Azores, Bukavu, and Bunia (Belgian Congo), Trieste, and Winsford and Bidston (England). Each observation requires about 40 days (including 10 days for the instrument to settle down after transit). These measurements are made to compare calculated and theoretical tides of semidiurnal and diurnal periods as a function of position on the earth and distance from the ocean. In addition, these data will be searched for the presence of disturbances with a period corresponding to that of free vibrations in the earth—about 55 minutes.

Latitude and longitude.—In cooperation with astronomers at the various observatories, special moon-position cameras developed by William Markowitz are in operation under the auspices of the U.S. Naval Observatory at some 20 astronomical observatories around the world. The Markowitz camera takes simultaneous exposures of the moon and surrounding stars, hold the moon's image fixed relative to the stars. Several observations taken on a single night fix the position of that station with reference to the center of the earth and without dependence upon a plumbline. The Markowitz camera is also useful in making determinations of uniform time, the moon performing a function comparable to the minute hand on a clock and the stars acting like the hour hand (4).

SYNOPTIC PROGRAM

The primary objective of the IGY was in the acquisition of data taken simultaneously at various points on the earth in order to give a planetary view of phenomena and events in most of the major fields of geophysics. Both space and time variations were important, and this accounts for the broad geographical coverage and for the 18-month period (July 1, 1957, to December 31, 1958).

World data centers.—This basic goal of the IGY was reached, for the observational program of the IGY was prosecuted even more effectively than anyone had hoped during the planning period. The evidence for this generalization lies within the three world data centers, established to maintain collections of IGY data. One of these is in the United States, a second is in the U.S.S.R., and a third has subcenters located according to scientific discipline in Australia, Japan, or any one of several nations of Western Europe.

World data center A comprises subcenters in 11 institutions in the United States. World data center B (maintained by the U.S.S.R.) is divided into four subcenters; three of these are in Moscow, while the fourth subcenter, for flare and plage indices, is in the Crimea. World data center C has subcenters in eight nations of Western Europe and in Australia and Japan, as follows: Meteorology (Switzerland), geomagnetism (Denmark, Japan) aurora (Sweden, Great Britain), airglow (France, Japan), ionosphere (Great Britain, Japan), solar activity (Switzerland, Italy, Great Britain, France, the German Federal Republic, Australia), cosmic rays (Sweden, Japan), glaciology (Great Britain), rockets and satellites (Great Britain), seismology (France), gravimetry (Belgium), and nuclear radiation (Sweden, Japan).

The status of data interchange within the IGY may be summarized by examining the data in the 11 subcenters of world data center A in the United States. By and large the record is an impressive one, indicating wholehearted cooperation in this as well as in the observational phase of the program.

Airglow and ionspheric physics (National Bureau of Standards).—After completion of the absolute calibration of IGY airglow photometers in the spring of 1958, data from the first year's observations from many stations reached the data centers. The flow of ionospheric data is immense. Data have been received from each of the other world data centers, and directly from 149 stations in 43 nations. Over 100 miles of ionogram film have been processed. The dispatch to other data centers of data received by center A is fully current. Interim catalogs on airglow and ionosphere were issued by the center in April and July 1958.

Aurora—instrumental observations (University of Alaska).—Data from instrumental auroral studies are flowing more slowly than anticipated. More time had been required for processing and reducing all-sky camera films and for transmitting them to the data center than was estimated in the schedule of the Special Committee for the International Geophysical Year (CSAGI). However, data have been received from 33 of the all-sky cameras operated as part of the U.S. program. Films have also been sent to world data center A from Canada, Chile, and the U.S.S.R. Center A is copying and shipping all-sky camera film on a routine basis to centers B and C, and to center A for aurora (visual observations) in support of the mapping program conducted at that center.

Aurora—visual observations (Cornell University).—The number of stations from which data are expected, by area, is approximately as follows: United States 500; Canada, 400; world data center B, 400; world data center C, 350. Some data have been received from about 1,100 of these. The center has IBM cards for visual observations up to October 1958 and hourly (in some instances quarter-hourly) auroral maps, provided through the U.S. Reporter, up to September 1958. The center has also received IBM cards for 1957 from the following U.S. antarctic stations: Little America, Ellsworth, and South Pole. Data and catalogs of data have been sent to the other world data centers. Data have been received from data center C and directly from Argentina, Canada, Cuba, Hungary, Mexico, New Zealand, and Rumania.

Cosmic rays (University of Minnesota).—Data are flowing regularly to data center A from centers B and C. Most stations send data directly to all world data centers. Data have been received at center A from 70 of 111 stations, representing 21 of the 38 nations participating in the IGY cosmic ray program. By October 1958, 12 months of data were due in; of the approximately 43 percent had been received.

Geomagnetism, gravity, and seismology (U.S. Coast and Geodetic Survey).—World data centers B and C act as collecting institutions and have forwarded some data to center A in that capacity. Data received in world data center A are forwarded regularly to the other data centers as required. Geomagnetic data have been received from 115 of 262 stations in 30 of the 49 nations participating in the IGY geomagnetic program.

So far the flow of gravimetric data has been small. Data have been received in world data center A from 26 of 230 stations in five of the 18 nations conducting earth tide studies: Argentina, Hungary, Iran, Italy, and Japan. Data have been received from 207 of the 398 stations conducting seismic observations. Bulletins containing seismic data have been sent directly to center A from stations or national collection agencies of 28 of the 52 nations which are participating in the IGY seismological program.

Glaciology (American Geographical Society).—Glaciological data from the traverses conducted during the antarctic summer of 1957–58 have been collected and processed at Ohio State University. The seismology and gravity data

from these traverses have been processed at the University of Wisconsin. All of these traverse data are now ready for transmission to the respective data centers. This center has issued the first volume of the "world date center A Glaciological Report Series." This volume includes preliminary reports received by the center prior to June 23, 1958.

Longitude and latitude (U.S. Naval Observatory).—Data from the two programs in longitude and latitude are reaching the appropriate primary data centers; astrolabe data are sent to Paris, moon-position data to Washington. These data will be reduced and published by the primary data centers. The flow of moon-position data commenced late because of delays in starting the observation program. Data for the moon-position program are originally in the form of photographic plates from the 20 moon-position cameras. These plates are sent to one of four measuring centers: Washington, the Cape of Good Hope, Paris, and Herstmonceux. Measurements are sent to the U.S. Naval Observatory for computation and publication.

Meteorology and nuclear radiation (U.S. Weather Bureau).—All stations in this discipline send their data either direct to world data center C (World Meteorological Organization, Geneva) or to center C via centers A or B. In accordance with CSAGI agreements, center C will reproduce all IGY meteorological data on microcards, which will be available to other interested persons or agencies. The flow of basic data from stations within the United States' area of responsibility is quite prompt. Data have been processed and machine listings have been made and shipped to world data center C as follows: Synoptic land, through May 1958; synoptic sea through May 1958; radiosondes, through April 1958; and upper wind through May 1958.

The flow of meteorological data from the various U.S. stations to world data center A, and thence to the World Meterological Organization, world data center C, depends on the communication facilities available and the time required for checking the data and transcribing them to WMO–IGY data forms. Data from stations in Antarctica, for example, come in only once yearly. Several months then are required for checking them and entering them on the WMO–IGY forms. At the same time that data are submitted to the World Meteorological Organization, selected data are also processed at the U.S. Weather Bureau's National Weather Records Center at Asheville, N.C., and put on punched cards. The flow of data to center A from the stations in North America alone amounts, on the average, to 25,000 punched cards per day; for the entire world network of stations, at least 100,000 cards per day would be required. The punched cards are most useful in analyzing the data and retrieving specialized information, for general use of scientists throughout the world, world data center C is making the data available on microcards.

The pattern for the flow of data on nuclear radiation was estalished several months after the beginning of IGY. Center A has received data in nuclear radiation from 47 of 420 stations in 11 nations participating in this program.

Oceanography (Agriculaural and Mechanical College of Texas).—Sea-level and long-wave data from 14 countries have been sent to world data center A. Most of the data received so far relate to the less extensive cruises or to cruises conducted prior to the IGY, although data have recently been received from nine major U.S. and two major U.S.S.R. cruises. Data have been sent to and received from world data center B and have also been sent to a permanent service for oceanography, the Liverpool Tidal Institute. Interim catalogs of data were prepared by the center in April and July 1958.

Rockets and satellites (National Academy of Sciences).—The section of the "CSAGI Guide" outlining the operation of the data centers for rockets and satellites was issued in April 1958 and revised at the Fifth CSAGI Assembly in Moscow in August 1958. At present, data have been received by world data center A from Argentina, Canada, Denmark, France, Germany, Japan, South Africa, the United Kingdom, the United States, and the U.S.S.R.

Because of the nature of rocket and satellite data, the agreed-upon timetable allows 12 months after completion of an experiment before published results are expected. In order to keep the scientific public informed during this period, world data center A for rockets and satellites initiated two series of reports containing interim and preliminary observations and results. To date, reports Nos. 1 to 6 of the "World Data Center A Satellite Report Series" and No. 1 of the "Rocket Report Series" have been issued.

Solar activity (high altitude observatory, University of Colorado).—Data flow very promptly in this discipline. Center A has received data from 24 of the 36 nations participating in the solar-activity program. In addition to the telegraphic data, written and tabulated reports are received regularly and promptly. Monthly lists of solar flares are dispatched by the seventh of the following month.

As part of the intermediate publication of data, this center has published "Reports of Surges and Active Prominence Regions" for the months of July 1957 to March 1958 (reports No. 1–3 of the World Data Center A Solar Activity Report Series") and "Observations of the Solar Electron Corona" for September 1956 to January 1958 (report No. 4 of the series). The center published a 12-month catalog of data on July 15, 1958.

The problem of data reduction is clearly a formidable one. Fortunately, information processes, techniques, and devices were available to the IGY, and much of the data, particularly in the fields characterized by large volumes, was reduced as it flowed to the subcenters of world data center A. The analyses of reduced data have already begun, but this task of analysis and interpretation will occupy theoretical-minded geophysicists and physicists for many years. Even several decades hence, the body of IGY data will provide a valuable reservoir for research, particularly in the light of the discoveries that will be made in coming years.

Meanwhile, the formal end of the IGY program, on December 31, 1958, does not mean the termination of international cooperation in geophysics. During the Fifth General Assembly of the IGY, in Moscow, it was agreed that during the year 1959 cooperation along the lines of the IGY would be continued. This program has been given the designation International Geophysical Cooperation, 1959 (IGC–59). Such studies as appear practicable to the participating IGY committees will be conducted as part of an internationally coordinated effort, with interchange of data, as in the IGY, under the aegis of the International Council of Scientific Unions. The Council has authorized the establishment of a Special Committee for Inter-Union Cooperation in Geophysics (SCG), which will assume responsibilities for IGC–59 similar to those that CSAGI assumed for the IGY. Moreover, those fields that particularly call for extensive and intensive studies are receiving attention. Thus, the Council has established special committees dealing with oceanography, the Antarctic, and space science. Counterpart committees have been established in these areas by the National Academy of Sciences, and significant steps have been taken for planning long-range programs in the above three fields, including activities for 1959. In addition, the Council has authorized the continuation of the solar patrol and related world communications services which proved so useful during the IGY both in studying solar activity and in alerting scientists everywhere to solar events that were apt to result in terrestrial effects. Finally, the Council has endorsed the proposal for a world magnetic survey during a quiet solar period, some 4 to 5 years from now.

REFERENCES AND NOTES

1. H. Odishaw, "International Geophysical Year (pt. I)." Science 128: 1959, 1958.

2. The preparation of this summary of IGY is based entirely upon reports and descriptions of projects supplied by the scientists and institutions engaged in the IGY research program. Many of them are mentioned in the text, although in this short summary it has not been possible to refer to all of the scientists who are producing contributions through their IGY programs or to describe all of the IGY accomplishments. The U.S. IGY program itself has been made possible only through the great contributions of time and effort of so many individual scientists and the participation and cooperation of public and private institutions. Particular acknowledgment should be made to members of the National Academy of Sciences' IGY staff who have assisted in the collection and preparation of the material contained in this article: Pembroke J. Hart and Stanley Ruttenberg.

3. H. Odishaw, "International Geophysical Year: A report on the United States program." Science 127: 115, 1958.

4. Data are being accumulated, and the results will appear in the bulletin of the U.S. Naval Observatory.

THE FUTURE

Dr. KAPLAN. I have already mentioned the legacy left by the IGY of 1957–58. I should add that each of the special international bodies that have been established has a U.S. counterpart in the Academy. These counterparts were in several instances concerned and recommended to Dr. D. W. Bronk, President of the Academy, before the special international committees were set up by the ICSU.

I want to call special attention to the part of my testimony which deals with IGC–59. Its history, the U.S.S.R. plans as described in general terms by Dr. Beloussov in the Pravda article that is part of my testimony, and the carefully considered U.S. plans are worthy of special note.

MEANING OF IGY

The IGY has had significant meaning for the sciences that make up geophysics as well as for such disciplines as astronomy, physics, chemistry and the life sciences. But it has also had a variety of meanings that have been usefully described by the Executive Director of the U.S. National Committee in some remarks before the National Press Club, December 4, 1958. I have a copy of these remarks before me and would like permission to insert them into the record.

The IGY has been a great human effort to which men have devoted years of their lives in dangerous and remote places. Some, unfortunately, have given their lives. Others have had close calls. Notable among these is the experience of Mr. Albert P. Crary of the Air Force Cambridge Geophysics Directorate, who is Dr. Wexler's deputy in the Antarctic and is the station scientific leader at Little America. His experience in falling into the cold antarctic waters off the ice shelf and his dramatic rescue is an outstanding example of the human experiences to which I referred. The evacuation of the Arctic Basin Drifting Station "Alpha" last fall is another such example. I could add to these two many others, such as the building and use of the rocket launching facility at Fort Churchill, where the United States and Canada cooperate so well. Its performance and future promise justify the heroic efforts to carry on rocket launchings in the arctic desert.

IGY—A USEFUL PATTERN

One of the characteristics of the IGY that has excited public response is its pattern of activity. Its success in bringing together all of our national resources in order that we might carry out our portion of the worldwide IGY program, has led others to propose similar programs in other fields. Its success has given greater stature to all of the groups that have been associated with it, and in particular to the ICSU, under whose structure the international effort was coordinated. The CSAGI, the special committee that ICSU established for the IGY, is not an elaborate bureaucracy. It is temporary, and it is unpaid. Its small secretariat is temporary.

Similar statements can be made about the relatively small, able, and devoted staff of the U.S. National Committee. I will not burden you with details because these have been presented in the Press Club talk to which I referred earlier.

I would like instead to emphasize that the national approach to science programs, so much in the news and in the minds of the Congress and others in the Government, might profit greatly from the pattern that the IGY has so effectively used. I, for one, believe strongly in this pattern of private enterprise and in the importance to us of giving continued support to this pattern both in our domestic as well as in our international scientific activities.

Finally, I'd like to outline briefly the rest of the hearing. First, you will hear from Dr. George P. Woollard, who will review and interpret the IGY programs in seismology, gravity, and latitude and longitude determinations. He will be followed by Dr. Merle A. Tuve and Dr. J. E. Oliver. The heat and water regimen of the earth will be discussed first by Dr. Roger Revelle, who will talk about the IGY program in oceanography and the future in oceanography. Dr. Revelle will be followed by Dr. Harry Wexler on the review and interpretation of the IGY meteorological and glaciological programs, with emphasis, first, on the Antarctic and, second, the Arctic. Dr. Reichelderfer will then discuss the overall aspects of meteorology with emphasis on programs of the U.S. Weather Bureau. Future interests in Antarctica; SCAR and its plans; NAS Committee on Polar Research and its programs will be presented by Dr. Wexler on behalf of Dr. Gould, who could not be with us today.

In the general area of space science, including the upper atmosphere, Mr. Shapley will lead off with the ionosphere, aurora, and airglow. He will be followed by Dr. Roberts on sun and earth relationships and by Dr. Van Allen on the IGY rocket and satellite programs. Finally, the future of space science; COSPAR and its plans; NAS Space Science Board and its program will be described by Dr. Berkner.

This, then, is the beginning of the Academy's report to the Nation.

Here I would like to go to the actual details of the testimony. I won't take the time to review the program.

Mr. THOMAS. That is a nice statement.

Dr. KAPLAN. The first person will speak about earth sciences and present the report on the earth sciences.

In each case since the speaker has prepared testimony, I would like to have permission to insert it into the record.

STATEMENT OF DR. GEORGE P. WOOLLARD CONCERNING SEISMOLOGY, GRAVITY, AND LONGITUDE AND LATITUDE PROGRAM

Dr. George P. Woollard, whose association is set forth in the document, Professor of Geology at the University of Wisconsin, is our first speaker.

Mr. THOMAS. Dr. Woollard, we are delighted and honored to have you with us.

(Dr. Woollard's prepared statement follows:)

Mr. Chairman and members of the committee, I am very pleased to have the opportunity to appear before this committee to discuss the work done during the International Geophysical Year in the seismology, gravity, and longitude and latitude programs. As it has been my pleasure to have participated actively in both the seismology and gravity programs, my remarks on both of these subjects will be tempered if not biased by a certain amount of personal feeling. As it happens, scientific progress in the fields of seismology and gravity has tended to be evolutionary. Many of the important discoveries and results in these fields have come about very slowly, as a result of years of painstaking research on the

part of various investigators both in this country and abroad. The great acceleration which work in these fields experienced during the IGY was most gratifying to persons such as myself who have devoted a major share of their lives to the study of this planet earth on which we live. I would like to discuss this work, and in the interest of time will make only abbreviated reference to that portion of the work which has been fully reported to this committee in the past.

I. U.S. SEISMOLOGY PROGRAM

The IGY program in seismology comprises three types of investigations: (1) seismological studies based on earthquake wave arrivals; (2) seismic exploration based on waves generated by explosive blasts; and (3) strain seismometer measurements between two nearby points. The program in earthquake seismology was a compound one involving the establishment of new observatories in locations where they would contribute a maximum amount of knowledge concerning the interior of the earth by virtue of their position relative to the areas of maximum earthquake activity; the installation of special, newly designed equipment at some observatories for investigating seismic waves travelling via all-oceanic or all-continental paths from the earthquake epicenters, and the establishment of new observatories in Antarctica in order to study the underlying crustal structure of that ice-covered continent. As earthquakes are classified as acts of God rather than man, and as we therefore had very little control over that part of our investigations, the scientific usefulness of these installations has not been fully exploited as yet. Although many interesting observations have been obtained, the program has been limited by the number and distribution of major earthquakes that have occurred since the stations became operative.

Of particular value has been the installations of long period seismographs in 19 observatories around the world. These seismometers, which are of a type recently developed by Lamont Geological Observatory and California Institute of Technology, are used for the investigation of long period seismic waves (periods from 50 to 600 seconds) whose very existence was not recognized until recently. The long period surface waves, known as Rayleigh waves, are propagated at great depths in the earth and through a phenomenon known as velocity dispersion provide a method of investigating the structure of both the earth's crust and the outer portion of the underlying mantle.

At two observatories, Huancayo, Peru, and Rio de Janeiro, Brazil, intermediate period seismographs were also installed for the study of surface waves known as L_g waves. These waves are short period shear waves propagated with a characteristic velocity of 3.51 kilometer-seconds in what appears to be a wave guide about 10–20 kilometers thick, which is peculiar to areas with continental type structure. The greater understanding of the L_g waves gained from these South American installations will contribute greatly to the investigation of the continental or noncontinental character of unexplored segments of the earth's crust. For example, despite the Russian claims that the Arctic Ocean is a foundered continent, analysis of seismograph records for L_g indicate it is truly an oceanic area.

In Antarctica, surface waves from earthquakes in the adjacent oceanic areas have been recorded at Wilkes Station and have been subjected to a dispersion analysis. This study has indicated that the average value for crustal thickness in Antarctica is three-fourths of the value considered normal for continents. This suggests that Antarctica is truly a continent, but that the continental area is much less extensive than the area of the ice sheet. Another surprising result brought out by the seismograph station observations in Antarctica is the lack of seismicity. Throughout the IGY period no earthquake was recorded whose epicenter lay within the antarctic continent. This lack of local seismicity therefore enhances its values as a place for studying the interior of the earth. All oceanic paths from Antarctica to active seismic areas at all ranges from the South Pacific to the Aleutian Islands, and to the earthquake zones in the Atlantic and Indian Oceans, are uncomplicated by intervening continents.

The two strain seismometers installed by Hugo Benioff of the California Institute of Technology in the Andes Mountains near Santiago, Chile, and in the town of Chosica, Peru, are giving much needed information on the actual strains developed in the crust, leading to earthquakes. Unlike ordinary seismometers which indicate only instantaneous motion at a point on the earth's surface upon arrival of seismic waves, these instruments measure both the oscillations of long period waves and long-term distortion in terms of the change in distance between two nearby points over a period of time. Changes in distance

are measured between two points about 80 feet apart by means of a length standard of fused quartz rod coupled between two posts with a magnetic sensing device so sensitive that it is possible to detect a change in this distance of about one-millionth of an inch. By using two such instruments mounted at right angles to each other, information is obtained not only on the strain developed and the direction of the stresses present, but also on the elastic and plastic properties of the outermost portion of the earth and the mechanism for the generation of earthquakes. With sufficient information, the strain pattern and habit of a region can be determined which would greatly enhance our understanding of earthquakes in any given area and ultimately would provide a basis for the prediction of earthquakes in that area. The site chosen for the installation of the extensometer in Peru has proved to be a very happy choice, since it is unusually free from background noise and hence is an ideal site for such delicate measurements.

As part of the IGY program in exploration seismology using explosive blasts, both the Carnegie Institution of Washington and the University of Wisconsin undertook measurements of crustal structure on the continents. The Carnegie Institution's measurements in the Andean region of South America, under the direction of Dr. Merle A. Tuve and the late Dr. Howard E. Tatel, have been reported in the past to this committee. While considerable difficulty was experienced in making measurements in the high plateau of Peru (elevation 9,000 to 10,000 feet), the thickness of the earth's crust does not appear to be more than 36 kilometers unless undetected layering is present. (If such layers are present, the thickness may be as great as 46 kilometers.) A good measurement, however, was obtained in northern Chile. There, at an elevation of only 5,000 feet, the thickness indicated is at least 46 kilometers and perhaps as much as 56 kilometers. These relations conform neither to the concept that the mountains have underlying roots which are in proportion to their elevation, nor to the observed gravity anomalies which would suggest that there is a thick crust beneath the Andean Plateau.

Earlier measurements made by the Carnegie Institution in the Colorado Plateau gave what might be termed abnormally shallow depths to the base of the crust in this area also. The average value for measurements at three sites was about 30 kilometers. The University of Wisconsin carried out measurements in a similar terrain during the IGY and found in the high plateau of Mexico a crustal thickness of 39 kilometers which, while greater than that indicated by the other plateau studies, was still less than would have been predicted from the gravity observations. In this connection, attention should be called to the results obtained from the Rayleigh wave dispersion studies of crustal structure in the United States, which suggest a thickness more in keeping with the gravity indications. The IGY program in the field of seismology has therefore raised a problem rather than solving one. Until the gravity, explosive blast measurements, and earthquake surface wave studies can be reconciled, we are confronted with a scientific enigma of the first magnitude and of extreme geologic importance because the plateau areas involved are areas which have risen 1 or 2 miles with little or no internal distortion during recent geologic time. The mechanism involved in this uplift may be the cause of the present ambiguity in results in the plateau areas in contrast to results obtained in other geologic provinces where there is excellent agreement between the modes of study. Plateaus, instead of floating like blocks of ice with large crustal roots beneath them as it appears the continents as a whole do, may have risen like so much bread dough by virtue of crustal or subcrustal expansion occasioned by physical-chemical changes in the rocks at depth, local thermal expansion, or some related phenomenon.

The other seismic crustal measurements carried out by the University of Wisconsin were in areas of abnormal gravity relations. These were in northern Michigan, northern Wisconsin, and in eastern Arkansas. These measurements showed that the crust was far less uniform in either composition or structure than had previously been supposed, and that the observed relations were quantitatively compatible with the gravity data and with information that exists concerning crustal structure from velocity dispersion of surface waves from earthquakes.

Seismic crustal measurements have also been part of the oceanographic program for the IGY. On the Scripps Institution of Oceanography's Expedition Downwind (Oct. 21, 1957–Feb. 28, 1958), seismic refraction and reflection studies were made by R. W. Raitt and G. G. Shor. A preliminary report of

this work was made to the committee last June. Of particular interest, in view of the Carnegie Institution's measurements in the Andes, are results of the marine measurements off the coast of Chile. Under the South American Trench, the crustal thickness measured is quite small (near 6 kilometers) and increases as one moves along the slope of the trench toward the shore and quite abruptly changes at the continental boundary to reach the value of 46 to 56 kilometers beneath the Andean foothill region. Therefore, while the change in surface relief is of the order of 30,000 feet in progressing from the trench to the Andean foothills, the subsurface change at the base of the crust is about five times as great. This value agrees very closely with that derived from our knowledge of the densities of rocks as to the amount of root to be expected for a floating crust. On this basis, a crustal thickness beneath the high Andean Plateau of at least 60 kilometers would be expected.

Under the East Pacific Rise (also called the Albatross Plateau), which is a broadly uplifted region some 200 miles wide and from 1 to 1⅓ kilometers higher than the surrounding oceans, the mantle velocity appears to be 7.6 kilometers per second, notably lower than the more usual 8.2 kilometers per second. Thermal measurements reveal that the heat flow in this region is much higher than normal, hence the temperature at the base of the crust is presumably much higher also, perhaps by as much as 500° C. Since one of the thinnest crustal sections measured to date, 4 kilometers, also occurs adjacent to this area, it is a region of considerable scientific interest. The situation is similar to that observed in the plateau areas of the continents. Here it appears that the greater elevation of the Albatross Plateau may be related to thermal expansion due to increased temperatures as evidenced by the heat flow measurements.

In the western Caribbean Sea, geophysicists of Lamont Geological Observatory have made 38 detailed seismic profiles during the IGY. In general, crustal thickness was found to vary inversely with water depths, a thin crust under deep water, a thicker and often more complicated crustal section under shallow water. Beneath the Cayman Trough, where the depth of water is as great as 7 kilometers, the crustal thickness is less than 4 kilometers, hence the total depth to the base of the crust is 10–11 kilometers. Beneath the shallower adjacent basins, the base of the crust is at some 14–15 kilometers. Beneath some of the shallow areas, the thickness of the crust was estimated to be 20–25 kilometers.

In the middle of the Colombian Basin, the generalized relations above do not appear to hold. The thickness of the crust is at least twice as great as that of the average Atlantic crust, although the depth of water is scarcely 1 kilometer less than average ocean depth. The Caribbean area therefore has turned out to be one of considerable geological interest. It has been generally thought that the area is in a state of long-range change, although it is not certain whether the region is rising or subsiding. The cross-section evolved from the seismic studies in the Caribbean Sea therefore reveals crustal structures of the type associated with ocean basins and of the type associated with continents occurring within 80 miles of one another.

Through the cooperation of Argentine IGY study groups, the Lamont Geological Observatory has also carried out extensive studies of crustal structure beneath the continental shelf of South America and established a series of measurements between South America and South Africa.

The other phase of the seismic program involved measurements of ice thickness in Antarctica along traverses based on the Byrd, Little America, Ellsworth, and McMurdo stations. As has been reported, an astonishingly greater thickness of ice has been found than had been previously supposed. As data from the various traverse parties have been worked up, it has become clear that the average thickness of ice is close to 10,000 feet and that the rock surface beneath the ice of Antarctica is below sea level under considerable areas and is above sea level by only a few hundred feet in other regions. The question soon was raised whether Antarctica was indeed a continent or was perhaps an island group bridged and covered by ice. There is now considerable evidence that the regions known as east and west Antarctica are two separate entities, eastern Antarctica being a continental mass, and western Antarctica an island archipelago. While removal of the load of ice would theoretically result in about a 3,000-foot rise in the land surface, the basic relations now defined seismically would still persist. The three traverse parties consisting of five to six men each, operating with two "sno-cats" and pulling sledges loaded with fuel oil and their equipment, covered approximately 10,000 miles along which gravity and magnetic observations were taken at about 10-mile intervals and seismic measurements of the thickness

of ice at about 30-mile intervals. The fortitude and scientific ability of these men who made the greatest contribution to our knowledge of Antarctica cannot be overemphasized. This year, supplementary measurements were made using a continuous recording magnetometer on aircraft which covered 2,500 miles of unexplored area. As these data can be used for making estimates of ice thickness as well as giving information on the subice geology, they will be extremely valuable. Eleven landings with aircraft to obtain seismic estimates of ice thickness and gravity readings were also made. This program unfortunately had to be terminated in the middle of the operating season because of the closing of the Little America station, which was being used as an operational base.

II. U.S. GRAVITY PROGRAM

The IGY gravity program consisted of five parts: (1) The establishment of standardization control points with pendulums along meridional lines for furthering worldwide coordination of values and the establishment of an international gravity standard, (2) the establishment of a world network of auxiliary control points with gravimeters principally at airports, (3) establishment of gravity values on the traverses in Antarctica and from the ice floe stations in the Arctic Ocean, (4) marine gravity measurements, and (5) earth tide measurements using very sensitive gravimeters. The meridional lines of pendulum measurements were a continuation of an earlier study started at the University of Wisconsin and the Woods Hole Oceanographic Institution. These measurements now extend from Point Barrow, Alaska to Punta Arenas, Chile; from Ottawa, Canada to Buenos Aires, Argentina; from Oslo, Norway, to Capetown, South Africa; and from Sapporo, Japan to McMurdo Sound, Antarctica. Along the first three of these lines, many of the same sites were occupied also by a team from Cambridge University, England, using another set of high precision pendulum apparatus. The results of this cooperative study indicate that for the first time we shall be able to define physically an international gravity unit with precision in keeping with the demands of modern physics and geodesy.

The program for the establishment of an international network of control stations (primarily at airports) throughout the world was also a continuation of an earlier study started at the University of Wisconsin and the Woods Hole Oceanographic Institution. The purpose of this program was to give a basis for integrating all gravity data, much of it taken in connection with commercial oil exploration studies, into a unified whole so that all existing gravity data could be used for scientific geodetic and geophysical studies. This program also included gravity interconnections between the various antarctic stations of the United States, New Zealand, Argentina, Great Britain and the Russian station at Mirny, as well as periodic connections from Fairbanks, Alaska, and Thule, Greenland, to the floating Arctic ice floe stations on which gravity observations were also being made.

Although the results from the traverse studies relating to ice thickness in the Antarctic are discussed in detail in another report to this committee, I would like to mention here that the gravity, seismic, and magnetic studies carried out on a systematic basis by the traverse parties also contribute much to the knowledge of the geology of the underlying rock surface, and the gravity values also to crustal structure and geodesy. The loan of a gravimeter enabled the British Commonwealth expedition to take gravity measurements along with their seismic observations right across Antarctica. This information will add materially to the scientific value of their program and overall knowledge of the Antarctic continent.

The remarkable development of the Graf sea gravimeter during the IGY was reported in detail at previous hearings of the committee. At the present time, two of these sea gravimeters are available, but their use has been restricted by the need for a suitable stable platform. While such platforms exist, their cost has made operations other than on the U.S. Navy vessel *Compass Island*, which has a suitable platform, prohibitive. Despite this handicap, it can be said that the development of this gravimeter has completely revolutionized the concept of gravity measurement at sea. During the first 30 years of gravity measurements at sea utilizing pendulums in submarines, perhaps 5,000 measurements were made, and these at great expense in money and time. Further, these measurements were confined to a few limited areas of the oceans. Now one can envision the rapid charting of gravity in all parts of the ocean regularly traversed

by shipping and eventually in the remaining portions of the ocean visited only by special research vessels.

The U.S. program for measuring earth tides by means of extraordinarily sensitive gravimeters has been mentioned in previous hearings. The special gravimeters used in this program are sensitive to changes in gravity of less than one part per billion. (This is approximately the change in gravity which the instrument would experience if it were elevated by one-eighth of an inch.) Under the direction of L. B. Slichter, of the University of California at Los Angeles, a total of 13 sites was occupied by such instruments: Glendora (California), Honolulu, Wake Island, Baguio City (Philippines), Saigon, New Delhi, Bermuda, the Azores, Bukavu and Bunia (Belgian Congo), Trieste, and Winsford and Bidston (England). The observations at each station required a total of some 40 days, 10 for the instrument to settle down after the disturbance of transportation and about 29 for the actual observations. At the present time, the earth tide data are being subjected to considerable computation. One of the main objects of this research is to determine the time relationship between the tide and the force causing the tide. The elastic properties of rocks have been investigated by laboratory techniques and the elastic properties of the earth have been investigated by seismic techniques. The period of disturbance represented by the earth tide is much longer than the longest seismic waves that have been recognized to date. It is, therefore, possible to extend our knowledge of the elastic behavior of the earth to these longer periods (lower frequencies). It is known that when the period of the disturbance becomes as great as hundreds or thousands of years, that the rocks behave more like plastic, although they behave elastically under the influence of seismic frequencies and presumably under frequencies corresponding to the earth tides. In addition, it is of considerable interest to search these data for indications of vibrations with a period of about 55 minuts, which corresponds to the period of "free vibration" of the earth.

III. U.S. LONGITUDE AND LATITUDE PROGRAM

The moon position program, under the direction of William Markowitz, of the U.S. Naval Observatory, became fully operational somewhat after the beginning of IGY. Moon position cameras of the type developed by Markowitz for the U.S. Naval Observatory were supplied to 20 additional observatories around the world. Plates from these cameras are sent to one of four measuring centers, and these measurements in turn are sent to the Naval Observatory for high-speed mathematical computation. From this work ultimately will come a more accurate determination of positions on earth and also an independent evaluation of the shape of the earth from that defined by gravitational anomalies. With the development of the satellite program and hence an artificial moon, it has also become possible by simultaneous optical tracking from different locations to accomplish the same objectives, and already it appears that the oblateness of the earth as determined from gravity and satellite observations differs in some detail from that which had been accepted up until now. The anticipated launching of a special geodetic satellite, equipped with a flashing light and a radio receiver for command purposes plus a radio beacon and transponder, will permit continous tracking throughout the day (limited to the twilight hours at present) and may yield further significant details about the shape of the earth and the positions of the continents relative to each other.

Mr. THOMAS. We will be only too glad to listen to you talk as long as you desire to.

Dr. WOOLLARD. It is a pleasure for me to be with you this morning, Mr. Chairman, and tell you a little bit about the program that is involved in the fields of seismology, gravity, and the geodetic measurements on latitude and longitude which were part of the IGY program.

To start off with, I would like to say that the information I am giving you now is not so much in the prepared testimony as material that I think might be of interest to this committee.

NEW SEISMOGRAPH LOCATIONS

These three fields, gravity, seismology, and geology, are all interrelated in sort of an interdisciplinary group. We can break it down into various types of studies. The first has to do with the study of the earth as a whole, regarding its crust, its mantle, and core. The IGY program set up 10 new observatories distributed at points throughout the earth where there was no coverage in order to have the locations that would give the maximum amount of information concerning the interior of the earth by virtue of their position relative to where do earthquakes occur.

The earthquakes are limited rather closely in points of occurrence to rather narrow belts in the earth. It is not a random distribution, and so in order to study the interior of the earth, it is highly desirable to have the observatories where they will cover the ranges and depths of penetration of the earth where they are of most importance. In the past, observatories have been set up on what you might call a basis of intellectual interest, in Europe, but the areas where they might do the most good are scattered out in the Pacific Ocean.

While there was no one there interested in earthquakes, while they were having them, for the most part, there was no interest in setting up a test station.

Mr. THOMAS. Will you list those stations?

Dr. WOOLLARD. Guam, Korea, Truk, Thule, and four new stations in Antarctica. It was a spot distribution that would give the maximum amount of distribution.

LONG PERIOD SEISMOGRAPHS

Then the other thing that related to this type of study is the establishment of stations with special instrumentation for the earth studies of certain types of waves, which Dr. Oliver, I believe, can discuss a little better than I and will take up when I get through.

There were 13 new installations on long-period seismograph for the study of long-period surface waves which give us a considerable amount of information concerning the structure of the earth's crust; also two installations on intermediate frequency installations for the study of what is known as lg waves.

STRAIN SEISMOMETERS AND EARTH TIDES

This was related primarily to the study of the crust and the mantle, rather than the core at greater depth. Also, in relation to this program, we had two installations, one in Peru and one in Chile, of what is known as strain seismometers which are for measuring very long-period earthquake tremors and also for measuring the accumulative amount of distortion in the earth's crusts which precedes occurrence of an earthquake.

These stations also should be correlated in the interdisciplinary group with the earth tide studies which are part of the gravity program. I think there were 13 stations involving 40-day installations at these places for studying what is the lunar period, let's say, on earth tides.

There is an earth tide, for example, each day. Well, under spring tide conditions we get up to about 3 inches. This means that the earth's crust has this fluctuation. As the elastic and plastic properties of the crust are measured, or let's say, are indicated indirectly by these measurements, and if we can couple these along with actual elongation measurements at these other points, this gives us a better idea as to how elastic the earth's crust is.

EXPLOSION SEISMOLOGY

Also, in connection with the study that we have on seismology, we carried out studies related to the structure of the earth's crust from explosive blasts.

In other words, we generated our own earthquakes, and observed the travel time data for the waves coming through and in this way got another measurement of structural thickness.

Several measurements of this type were carried out at various places but the thing is that on these studies regarding the earth, we have not only seismology involved, but we have the earth's gravitational field involved because as I said, we are measuring the extension with the strain seismometers, earth's tides with gravity. We can use gravity for measuring how thick the earth's crust is. Part of the measurements are carried out by the Carnegie Institution in the elevated regions in Chile and Peru, by the University of Wisconsin in the high plateau of New Mexico, and three other sites in the United States.

There was a very extensive program carried out by the Scripps Institute in the Pacific, and by Lamont Geological Observatory of profiles across the Caribbean Sea, and quite a few measurements over the coastal shelf area off Argentina, which was a cooperative program with the Argentine IGY Committee, and also a profile that went from—between south Africa and South America. This program is still being continued at the present moment.

Measurements are being made off Cape Horn right now.

The other phase that we might put into this group is the traverse type of measurement which was made in Antarctica, also using blasts, to determine how thick is the ice. Here we have an interdisciplinary connection between glaciology in terms of how thick is the ice, and on the same traverses, in addition to making seismic measurements we carried out gravity and magnetic measurements. The gravity measurements could be used to determine what is the thickness of ice, the magnetic measurements would tell you which of the gravity measurements were related to changes in geology and which in changes of topology at the base of the ice and this same material could also be used to study the shape of the earth.

THE SHAPE OF THE EARTH

You recall in Time and News Week there was an article stating the earth was shaped like a pear, on the basis of data submitted by the satellites in this respect. The gravity observations we took on the Arctic ice pack, and the gravity observations taken in Antarctica, especially at the South Pole, more or less indicate that these conclusions are quite correct, but I should also point out that the con-

clusions that we first reached from the gravity observations did not indicate there was anything wrong with the shape of the earth. We concluded it was all in the crust of the earth, but there were indications from the study of the surface waves from the seismological stations that were established in the Antarctic that the conclusions based on gravity regarding the crusts were wrong. Gravity indicated a thick crust; seismic observations indicated the crust in Antarctica was thinner than it should be. We were at a loss to explain this until the satellite observations came along and said this was really the shape of the earth and not the crustal formation. All of these things are intimately tied up when we start talking about seismology, talking about gravity and start talking about the shape of the earth, itself.

Then we have another program.

Mr. THOMAS. What does the thickness of the crust at Antarctica have to do with the shape of the earth, whether it is round or shaped like a pear?

Dr. WOOLLARD. This has to do with gravity anomalies. We have to compute them on the basis of an assumed shape of the earth.

This has always been based upon the degree of polar flattening due to the rotation of the earth itself. The difference between a theoretical value which takes into consideration this plus the elevation, plus density of the material, and the observed value, we call the anomaly. We came up in the Antarctic with negative gravity anomalies which were much too large to be explained by the amount of ice present.

Mr. THOMAS. The only thing this discovery did, then, was to change your basic assumption?

Dr. WOOLLARD. It changed our basic assumption. The satellite came along and verified that the new assumption was correct.

THE GRAVITY UNIT

The other part of the gravity program I might mention involves several types of things: One of them was the determining of a physical quantity for what is the gravity unit. Although gravity has been used for many, many years, and in round numbers has been pretty well known for many, many years, in fact, ever since Cavendish back about 1700, something we found was, that each country was using a different unit. Before we had the international meter, the standard of length was not the same from one country to another. Part of the IGY program was to take pendulums and from changes in the period of these pendulums determine what was the actual variation of gravity, from the Equator, more or less, to the poles. In order to make this international so that everyone would have comparable measurements, we set up several lines of measurements: One, for example, goes from Point Barrow right on through to Cape Horn; another one starts on the island of Hokkaido in Japan and terminates at McMurdo, and another one starts at Oslo and goes to Capetown, South Africa, et cetera.

We were fortunate in getting the British IGY group to cooperate on this with another set of pendulums, so we have duplicate sets of pendulums at least covering three of the lines that were established.

Another phase of it was that in order to utilize what gravity data we have on the earth, particularly a lot of oil company data that has been established in connection with prospecting for possible geologic structures that may be associated with oil deposits, a lot of gravity data has been taken. This material, however, is sort of on a floating basis. In other words, it is relative to the steps of the Baptist Church, for example, and was not tied into anything on an absolute datum. We were trying to set a network of stations at the principal airports throughout the world that would allow tie points so that we would have a jumping-off place to connect these oil company surveys so they could be brought into the world network and, therefore, be used for geodetic surveys or studies of the crust or whatever particular scientific discipline for which you were interested in using gravity. There was something like 2,000 observations made of this nature.

GRAVITY AT SEA

Another phase of it was the measurement of gravity at sea. Up until the IGY, any measurements made at sea required a pendulum apparatus and also the use of a submarine. It was very unfortunate that we were unable to get a submarine, for example, commissioned for this work during the IGY, so we actually had no gravity observations at sea as part of the IGY program, although it had been officially part of the program.

Some measurements were taken by the Hydrographic Office but these were independent of the IGY effort. In fact, I think they were even classified. The thing is, during this period a new shipboard gravimeter was developed and tested on a run from the United States across to the Mediterranean and back, which showed that this could be done from the surface vessel if you had a stabilized platform.

At the present moment, we have not been able to get a ship that we could use for this, because of the lack of a stabilized platform. There is only one survey vessel, for example, in the Navy that has a platform. This is tied up on other duties so that except for this one traverse, we did not gain too much information. It was a test run.

EARTH TIDES

Another phase of the gravity program has to do with earth tides. This was extremely important in connection with the elastic properties of the earth's crust. On the ice floe stations in the Arctic we had gravity instruments measuring gravity twice a day as the ice floes moved. In fact, what information we have was obtained from this type of material. This program in gravity was quite large.

GEODETIC PROGRAM

The satellite program came into the same thing we are talking about because it was developed more or less concurrently with the IGY and, whereas, originally the latitude and longitude program was based on using a camera for studying the moon from different positions on the earth, and using stellar triangulation on the moon to determine the distance between points on the earth, this is something we do not know very exactly.

For example, each nation has a geodetic datum. There is a European datum that everything is referred to in Europe except for the countries behind the Iron Curtain. There is a North American datum taking care of Mexico, Canada, and the United States. But the relationship between the North American datum and the European datum is on the order of 700 to 1,000 feet. In going across to Tokyo the uncertainties were even greater. We had no way of interconnecting continents. Gravity is one way of doing this.

On the study of the satellite we found two things. One was that there was an error as to the shape of the earth. It was found not to be pear shaped but there was found to be a degree of flattening. It appears the earth is $\frac{1}{297}$ flattened instead of $\frac{1}{298}$, as we had been using.

If we take what gravity data we have, which is sparse on the oceans so we do not have full coverage, it did look as though this was a more reasonable number than we had been using.

The satellite has already from the geodetic standpoint shown up many things of particular interest from the standpoint of geodesy, and undoubtedly we will be changing the shape of the earth very quickly on the basis of these observations plus those carried out for gravity. So much on the program that was carried out and its objectives.

STRUCTURE OF ANTARCTICA

I would like to say that quite a few things that we had hoped for were not accomplished. For example, on the crustal studies we know Antarctica, for example, has roughly 10,000 feet of ice over it. This is a transient load put on the crust by nature. We know the rock surface over much of Antarctica is depressed very close to sea level or actually below sea level.

It appears that the earth's crust is elastic. Think of it as being like a sheet of ice with a man standing on it, depressed down by the weight of the man. If the man gets off, it will pop up again. We can expect Antarctica to do something of the same.

After even a crude calculation, for example, it appears that the eastern half of Antarctica is a continent and the western half is an archipelago of islands bridged over by ice.

ICE CORES

Mr. THOMAS. How deep have you penetrated through that 10,000-foot covering of ice?

Dr. WOOLLARD. The deepest is about 14,000 feet of ice.

Mr. THOMAS. Our understanding 12 months ago was that it was part of the plan to take a core. I do not know how deep the core was to be taken. Did you take any cores?

Dr. WOOLLARD. They have two holes that go down——

Dr. WEXLER. The first core at Byrdland was 1,013 feet, the second at Little America is 1,050 feet. We hope to go down through the entire 14,000 feet as soon as we develop new drilling techniques.

Mr. THOMAS. Did you make a study of all cores all the way down?

Dr. WOOLLARD. Yes. I should mention that volcanic ash has put a very beautiful marker on these cores so it will be possible to study

rates of accumulation by determining what depths this volcanic ash occurs, because it was laid down simultaneously over the whole area. This will help out a great deal in the study of the Antarctic.

Dr. BRONK. What is the oldest ice you have been able to determine?

Dr. WOOLLARD. I have no figures on that.

Dr. WEXLER. About a foot a year seems to be the current accumulation. They have gotten down to a thousand years ago.

Mr. THOMAS. You mean that ice has not melted in a thousand years?

Dr. WEXLER. It has just built up.

Mr. YATES. Have you learned anything from it?

Dr. WEXLER. We learned it was laid down apparently in a colder climate than now.

Mr. YATES. Have you discovered anything such as the geologists discovered in layers of rock?

Dr. WEXLER. That is being analyzed now but the same thing is found in Greenland. They have a 1,400-foot hole and are finding the same degrees of temperature, which indicates both the north and south polar regions were once much colder.

Mr. THOMAS. Proceed, Doctor.

Dr. WOOLLARD. Briefly, in connection with this continuing IGY study, there are more traverse studies in Antarctica. The map shows sampling is very sparse as to what underlying geology looks like, what the depressions look like. We need crustal blast measurements in order to find out what happened to the base of the crust to see how the base has gone down.

Mr. THOMAS. You are not looking for any oil when you go down beneath 5,000 feet, are you?

Dr. WOOLLARD. I doubt that we will find oil there. The gravity measurements at sea really have not gotten off the ground. The standardization measurements are not complete. We would like to get one on the west coast of Africa.

The port stations for the gravity program at sea, which would have been used as tie points for stabilizing that program, were only started and there was not too much done on that.

Certainly on the crustal measurements we have carried out on the continents, we just found out the problem is a lot more complex than we thought. The earth's crust is far from being uniform.

Mr. THOMAS. One further question and then I will not interrupt further.

I assume you are taking temperatures as you core. Dr. Wexler said the deepest hole was about 1,100 feet. What was the difference in temperature at the 800-foot and 1,100-foot depth?

Dr. WEXLER. In the case of Little America, at the bottom it was almost the temperature of freezing water, 25° F. The drilling stopped before it got into the ocean or it would have fouled up the bit.

At Byrd Station with no ocean underneath, it was much colder, 29° below zero centigrade.

Dr. WOOLLARD. That is all I have that would be of interest to this committee.

Mr. THOMAS. Thank you very much. That is wonderful.

Statement of Dr. Jack Oliver Concerning Special Seismological Programs

Dr. Kaplan. The next speaker will be Dr. Jack Oliver, who is new to the committee. He is project director for our IGY program in seismology and a research geophysicist at the Lamont Geological Observatory, Columbia University.

Mr. Thomas. Thank You, Dr. Oliver, for coming to give us your thinking on this valuable subject. We will be delighted to listen to you as long as you want to talk and we hope you will come back to see us again and again.

Dr. Oliver. Mr. Chairman and members of the committee, the subjects which I am to discuss are the LP and LG programs in the field of earthquake seismology. As you will recall, three programs included the operation of seismographs especially designed for the recording of seismic waves of long period and, in two cases, of waves of the shorter period LG type, at 13 stations throughout the world. The stations included are: Hong Kong; Honolulu, T.H.; Rio de Janeiro, Brazil; Santiago, Chile; Buenos Aires, Argentina; Suva, Fiji; Resolute Bay, Canada; Uppsala, Sweden; Mount Taukuba, Japan; Poona, India; Lwiro, Belgian Congo; Cape Hallett, Antarctica; and Huancayo, Peru. The instruments were acquired and, in some cases, installed by the United States, and then operated by local seismologists. Use of these records is shared by the operating seismologist and seismologists of Lamont Geological Observatory, which will be the ultimate repository for the records. Bulletins from these stations are sent to the world data centers in accordance with CSAGI agreements.

This program is considered to have been highly successful. The percentage of excellent data received was well above expectations. Of course, data analysis is still in a preliminary stage and far from complete, but many very significant results in addition to routine data reduction have already emerged.

Mr. Thomas. May I interrupt? Those 13 stations you mentioned. I was trying to follow you but you were jumping quite rapidly. You virtually covered the entire crust of the earth's surface, did you not?

Dr. Oliver. That is right. We missed one continent. Australia, and we had one there.

Mr. Thomas. You were not too far away from Australia, were you?

Dr. Oliver. Fiji, Cape Hallett, Hong Kong.

Mr. Thomas. Would it be with some degree of accuracy to say you virtually covered the entire earth's crust?

Dr. Oliver. I think we covered it about as well as possible with 13 points.

Mr. Thomas. Go ahead.

Results of the Program

Dr. Oliver. These results may be divided into two categories: (1) the discovery of new kinds of seismic wave propagation, which leads to new methods of exploration of the earth's interior; (2) exploration of the earth's interior by the new methods as well as the conventional techniques.

In the first category, we have the following: (*a*) explanation of the mechanism of propagation of longitudinal waves with periods of 10 to 50 seconds, (*b*) experimental data on waves of the second shear mode, previously predicted theoretically but never observed, (*c*) explanation of previously unexplained waves traversing oceanic paths with periods of approximately 8 seconds, (*d*) the first quantitative explanation of the group velocity maximum, or so-called Airy phase, recorded when the path is oceanic, (*e*) continuous measurements for the first time of background noise in the earth with periods between 10 and 20 seconds. All of these discoveries will improve the quality of our determination of the structure of the earth's interior.

In the second category, we have completed or have underway studies of structure of the crust and upper mantle in the regions of the Fiji Islands, in Africa, in Eurasia, in South America, and in the region of the South China Sea. As one example, I might cite the determination of an average crustal structure for a part of Eurasia which agrees well with the average of detailed results obtained by the U.S.S.R. at a few discrete points in this region.

Let me emphasize again that these results, although quite substantial in themselves, will be increased manifold before data analysis has been completed.

I know, for example, we have taken waves with a period of the order of 5 and 6 and 7 minutes. Although they are surface waves, they will give us information about the deeper parts of the earth's mantle.

DETECTION OF UNDERGROUND EXPLOSIONS

I might also point out that this increase in our knowledge of seismology has taken on additional importance in light of current and future negotiations on control systems for the detection of nuclear weapons testing.

As you know, the only way we have to detect underground explosions now is the seismic method, and this information we have learned will be of considerable help in this particular field. So it will help in our negotiations for a control system.

Thus, the scientific results from these programs have been highly rewarding.

Mr. THOMAS. Will you elucidate on that? You have alluded to a very touchy point there. Will you spell that out a little more in detail, please. What do you mean by negotiation and with whom, and on what?

Dr. OLIVER. I do not want to make a political decision as to whether we should be negotiating or not.

Mr. THOMAS. You are speaking purely as a scientist now?

Dr. OLIVER. What I am saying is if you want a control system——

Mr. THOMAS. Control system for what? Spell it out to us.

Mr. YATES. Control what?

Dr. OLIVER. To detect any violation of agreement on nuclear weapons testing.

Mr. THOMAS. To detect nuclear explosions. The doctor has just testified perhaps the best test available was the underground explosion. Go ahead from there.

Mr. YATES. He said they are discovering better methods of detecting underground explosions.

Mr. THOMAS. Maybe that is it.

Dr. OLIVER. If one wants to consider such a system, the more you know about seismology and how waves propagate the better position you are in to set up such a system.

Mr. YATES. Can you elucidate a little? Mr. Thomas wanted you to expand because this is of great significance to Members of Congress who are wondering about control systems for nuclear tests. Can you seismologists detect an explosion that occurs in Siberia or in Red China?

Dr. OLIVER. This is a very complicated question.

Mr. YATES. That is right. But we want to know the answer.

Dr. OLIVER. It depends a great deal on the size. If you are talking about a large hydrogen bomb, they can be detected all over the world.

Mr. YATES. How minimal an explosion can you detect?

Dr. OLIVER. This is where the problem becomes very difficult. It depends on the particular distance. It is not a simple relationship of distance. It depends on noise at the particular station, depends on the conditions under which the explosion was fired. If it was fired in the air, it is different; if it is fired in the lower part of the atmosphere, it is different from that which may be fired in the upper part of the atmosphere. It is different if it is fired underground or underwater. It is different if fired in different materials.

Mr. YATES. Are you seismologists going to be the ones who will be able to detect it or are there other devices?

Dr. OLIVER. Underground explosions?

Mr. YATES. Yes.

Dr. OLIVER. As far as I know, seismology would be it.

Mr. THOMAS. That is the simplest of all, underground explosions. What about the explosion 5,000 feet in the atmosphere and over water? You have a problem there.

Dr. OLIVER. There are other methods. One of the most difficult environments is the underground. There are other methods of detecting waves at least in the lower part of the atmosphere.

Mr. THOMAS. Go ahead.

CONTINUATION OF WORK

Mr. OLIVER. We get too far from seismology if we get high up. The results of the program have been highly rewarding. These programs have been equally successful from the standpoint of international cooperation in science. In fact, many stations are continuing this work voluntarily beyond the IGY.

Mr. THOMAS. Wonderful. Who is supporting the stations that will be continued? How many of the 13 will be continued? Your early statement indicated these stations were partially equipped, to say the least. I did not understand you to say what number of the 13 were with American-made equipment, but they were manned by scientists from various countries that make up the participation in the IGY.

Will the same group of scientists continue to man these stations?

Dr. OLIVER. They will man them, we are going to continue to supply photographic material.

Mr. THOMAS. Who is "we"?

Dr. OLIVER. The Lamont Observatory, supported by the Department of Defense.

Mr. THOMAS. Thank you very much. That was very helpful.

STATEMENT OF DR. MERLE A. TUVE CONCERNING FUTURE PERSPECTIVE OF GEOPHYSICS

Dr. KAPLAN. Again on the same subject, Mr. Chairman, we have Dr. Merle A. Tuve, member of the National Academy of Sciences, U.S. National Committee for the International Geophysical Year; member of the NAS Committee on Polar Research, and Director of the Department of Terrestrial Magnetism, Carnegie Institution of Washington.

Dr. TUVE. Mr. Chairman and members of the committee, I greatly appreciate the warmth of your welcome here and I also have much respect for the need for brevity in these hearings on the Hill. As you have listened to the reports of my colleagues and fellow enthusiasts, to whom I yield no precedence in my evaluation of the importance of these new things we have learned about geophysics, I decided I would try to back off a little bit from the details of the geophysics and share with you a little of the perspective which has been part of our discussions in the executive committee of the U.S. National Committee as well as in the meeting recently of the U.S. National Committee itself.

You are going to hear in this testimony a tremendous emphasis on the importance of geophysics and the future things to be done in geophysics. I would like to share with you a little of the perspective. It will sound as though we want to drive home the importance of expanding activities in geophysics above all other considerations.

I would like to say the members of our National Committee and its executive committee have discussed this in some detail and we agree that it is proper for a certain amount of deemphasis on geophysics. We have shared the important position among the sciences during the IGY; we have occupied a kind of spotlight. We do not feel it is inappropriate to back down in this emphasis, I would say, rather by emphasizing other areas of science.

Let me point out that the things we are talking about here are the lands of the surface of the earth. They have been fought over since men came out of bearskin robes. The oceans have been fought over, but here we have 66 nations busily exchanging with each other all the detailed information they can get on their own countries and on other countries and sharing such things as knowledge of the upper atmosphere, knowledge of the transmission of waves in the earth, detailed geological knowledge, detailed knowledge of the bottom of the sea.

Perhaps the most important result of the IGY is the demonstration that the people of the earth, despite their differences, can get together and work with complete wholeheartedness in studying things which are of concern to all of us and which could be of great nationalistic value if they were emphasized from a selfish point of view.

I don't believe I am willing to yield to my good friends here at the table any precedence with respect to enthusiasm about the nuggets of gold that have come out of this geophysical year. We have sat through a good many vigorous sessions, I believe 36 in the executive committee of the IGY.

Mr. THOMAS. Will you yield for a small note? Dr. Revelle found a lot of those nuggets, a little deep, about 8,000 or 10,000 feet down. He may not give them up even after diving down and getting them.

Dr. TUVE. I was speaking of the personal enthusiasm for geophysics results. It has been important enough to me that I treasure the memory of the lonesome trek at 16,000 feet in the Andes. The air was pretty thin for an old man like me, but the things we were measuring were mighty precious.

With that remark, let me go away from geophysics and say we want you gentlemen to view the IGY from the standpoint of an experiment in public administration and international cooperation. I think this has in it the germ of something much larger than, let us say, the content of three fine new textbooks on geophysics, however much that may be valued by us.

This example of international technical people working together with the best each nation has to achieve results for the good of all peoples is something we would like to see carried over into areas such as biological research, medical research.

I would like to suggest when I said deemphasize geophysics, you do it rather by emphasizing the other things. Geophysics has not lost its importance, but this example of the use of, if I may, the use of willing citizens quite outside of their actual structure of government to spend their time and effort on a limited time basis has many values with respect to the usual problem in all governments of empire building.

Here is a mechanism. I am not pleading for the Science Foundation to continue its generous use of the National Academy of Sciences. There are other mechanisms that can be used. But I know we have regarded it as a very valuable experience to have been part of the functioning of Dr. Waterman and his men, without at the same time feeling we were part of a government group which was committed to a particular thing. We felt complete freedom, I would say, as far as I know, in trying to assess the importance of the problems to be met and the allocation of funds, regardless of any—I hope I am not too interested in this—any political considerations. Of course, all scientists are minor politicians and do what we can to keep each other content.

Mr. THOMAS. As far as this committee is concerned—and I am sure I speak the sentiments of the Congress generally—there was not even any minor politics in this.

Dr. TUVE. Gentleman, I think this is perhaps the most important result of the IGY. Gentlemen of the IGY, let me point out one thing to you. Perhaps the most permanent record of the IGY was an opera on Johannes Kepler written by Paul Hindemith, which he brought out in the first half of the IGY. Possibly this will be remembered long after the details of our work.

Mr. YATES. Can you understand his music?

Mr. THOMAS. Is there any doubt why he is a favorite?

Dr. KAPLAN. Mr. Chairman, in each of the cases except, I think, Dr. Tuve we have prepared testimony and may I assume this will be entered into the record.

Statement of Dr. Roger Revelle Concerning the Oceanography Investigation

The next group of speakers will speak about the heat and water problems, the heat and water regimen. Once again our first speaker, Dr. Roger Revelle, will talk about the water program in oceanography and the future in oceanography. He is the director of the Scripps Institution of Oceanography, University of California, and I suppose it is now called the University of California at La Jolla.

Mr. Thomas. Dr. Revelle, it is nice to see you again. Dr. Revelle is a member of this committee, too. He is an oldtimer. For the record, I imagine you have a new boat coming up.

Dr. Revelle. I am glad to be here, Mr. Chairman. Is is a pleasure to have a chance to talk to this distinguished group of scholars on this committee.

Mr. Yates. It is a good thing we do not have to take a test.

Dr. Revelle. Today I brought along these props. First I brought along a very long statement of some 38 pages.

Mr. Thomas. We will put every word of it in the record.

(Dr. Revelle's prepared statement follows:)

RESULTS OF THE IGY OCEANOGRAPHIC INVESTIGATIONS; FUTURE U.S. AND INTERNATIONAL PROGRAM IN OCEANOGRAPHY

I. IGY Program

Mr. Thomas and members of the committee, it is indeed a pleasure to appear before you again to summarize the U.S. IGY program in oceanography and to discuss with you what we think this program means to the future geophysical work in this country.

Aside from the actual accomplishments of the IGY programs in terms of new discoveries and new and better observations, U.S. oceanographers have also had many opportunities to meet with oceanographers from other countries and even to participate in work on oceanographic vessels of other countries. When I first spoke to this committee in May of 1957, for example, I told you of the very important program carried out in the Atlantic Ocean by *Atlantis*, of Woods Hole Oceanographic Institution, and *Discovery II*, operated by the National Institute of Oceanography, England. During the IGY there have been many more such examples. In the Atlantic Ocean, Argentine, Brazilian, and South African vessels joined *Vema*, of Lamont Geological Observatory, in cooperative programs, and there was exchange of scientists between the ships of these countries. Woods Hole scientists worked on *Discovery II* during several cruises collecting additional important information in the North Atlantic Ocean. Similarly, in the Pacific, two Colombian frigates played an essential part with our Scripps ships in studying the equatorial counter current.

In November 1958 the U.S.S.R. research vessel *Vityaz* put into port in Vancouver, British Columbia. Dr. Richard H. Fleming of the University of Washington went to Vancouver to visit the ship. He was cordially received and learned that his work and books were well known to the Russian oceanographers. Dr. Fleming had a most informative visit with them. Later, *Vityaz* put into San Francisco. Her scientists and crew were welcomed by representatives of the U.S. National Committee, by the officials of San Francisco, and many scientists from my own institution, Scripps Institution of Oceanography, who traveled to San Francisco for the occasion. The Russian scientists conducted an extensive tour on board their vessel and engaged in detailed and thorough exchange of information and scientific ideas. Ten of the Russian scientists were flown to La Jolla where they visited the Scripps campus. Scientific discussions were held with members of the Scripps scientific community. Al-

together this was a fine opportunity to inspect in detail one of the largest oceanographic vessels in the world and to learn first hand from our Russian colleagues about their techniques and progress. *Vityaz* also visited Honolulu just a few weeks ago. The Russian scientists met with American scientists from the various research organizations in Hawaii.

On other occasions, such as during the Fifth General Assembly of CSAGI at Moscow, American oceanographers who attended this conference participated in scientific discussions with their colleagues from other countries and had the opportunity to visit some of the U.S.S.R. educational and research institutions. But now I should like to tell you more about the actual U.S. program itself which we have just completed.

Oceanographic work in the Pacific Ocean

The Department of Oceanography of the University of Washington completed two very important cruises with their research vessel *Brown Bear* in the Northeast Pacific Ocean. They made observations on the flow of water through the Aleutian passes and the exchange of water between the Bering Sea and the Pacific Ocean. They collected deepwater samples in the Aleutian Trench which they are now analyzing chemically and by radioisotope tracers to determine the age and origin of this water. They also made observations and measurements of the anomolous warm-water masses which have recently been observed in the Pacific Ocean. University of Washington scientists have also developed their techniques of chemical analyses to the point where the water samples taken on the cruises were analyzed on board ship and the data were rapidly converted to punchcards. This allowed immediate corrections to be made as well as reductions of the observations to the standard depths used by oceanographers.

In the tropical and South Pacific, three extensive cruises were completed by Scripps Institution of Oceanography. When I appeared before this committee in 1958, I described for you briefly some the findings of the first of these cruises: The mapping of Nasca Ridge, the Albatross Plateau, and the Peru-Chile Trench; the study of the flow of heat through the Pacific Ocean from the interior of the earth; and the discovery of areas where low-grade deposits of manganese, cobalt, nickel, and copper exist in very large quantities on the sea floor. Several companies are now giving serious study to the possibility of mining these deposits. In the meantime, the various scientists at Scripps who participated in this effort have worked more on the data taken during the cruise and a comprehensive preliminary report has been published in cooperation with the U.S. National Committee for the IGY, World Data Center A, and the National Academy of Sciences. In 1958, I also mentioned briefly the preliminary results from the second cruise undertaken by Scripps, when a great subsurface current, flowing toward the east some 3,500 miles long and carrying approximately 1,000 times as much water as the Mississippi River, was explored and mapped. The third IGY cruise shortly thereafter studied the equatorial counter current. They found that, contrary to previous ideas, this eastward flowing current extends downward to at least 1,000 meters and carries twice as much water (about 2,000 times the flow of the Mississippi) as had previously been supposed. The preliminary description of these current systems has already been reported in the scientific literature and comprehensive papers are now in preparation.

Other aspects of the U.S.-IGY oceanography program in the Pacific are the observations taken not on ships but on some 32 islands spread throughout the vast expanse of the Pacific Basin. Some difficulties were encountered at these stations which range from Hawaii to Koror and as far south as Pitcairn. Heavy waves and hurricanes destroyed some of the instruments and the lack of communication made some of the operations at remote stations difficult. Even so, local inhabitants, schoolteachers, weather personnel, and private citizens cooperated enthusiastically; they kept the instruments in operation and braved rough seas in small boats to take the necessary measurements and water samples. Scientists at the Scripps Institution are analyzing these data in the hope of understanding the long period waves which are generated by great storms at long distances, the monthly changes in sea level, and the seasonal exchange of water between the Northern and Southern Hemispheres.

Atlantic Ocean

Scientists of the Agricultural and Mechanical College of Texas completed a cruise with their research vessel *Hidalgo*. They studied currents in the Gulf of Mexico, in the Florida Straits and various tributaries of the Gulf Stream in the

western Atlantic. They took many water samples of large volume and are studying the geochemistry of various metals and radioactive isotopes. These Texas scientists are also engaged in an extensive study of how carbon dioxide is absorbed by sea water.

Lamont Geological Observatory carried out long cruises with their research vessel *Vema* in the southern Atlantic, studying the crustal structure of the ocean in cooperation with ships of other countries; they studied also the distribution of carbon dioxide, the distribution of radioactive isotopes and made extensive use of underwater cameras and sediment coring apparatus to study the ocean floor itself. One of their cruises in the summer of 1958 took them around the Cape of Good Hope into the Indian Ocean and from there into the Red Sea, where for the first time two-ship seismic profiles were made in this area of extremely interesting geological structure. The research vessel *Atlantis* from the Woods Hole Oceanographic Institution cooperated in this part of the *Vema* cruise. Lamont scientists have also extensively explored the earth crust in the Caribbean. Based on preliminary examination and study of their data they believe that this is an area of continental growth.

The research vessel *Crawford* of the Woods Hole Oceanographic Institution completed 12 sections across the Atlantic Ocean. In all of these sections many oceanographic stations were occupied and water samples obtained from the surface to the bottom. The temperature profiles across the North Atlantic shows that effects of the Gulf Stream can be seen all the way to the bottom. When all the sections are analyzed and the results plotted, scientists will be able to study as never before the large-scale circulation features of this important body of water. One of the products of the Woods Hole work will be a new atlas of the water masses of the Atlantic. Woods Hole scientists have also specialized in the study of certain chemicals and radioactive isotopic components of the ocean water and their determination of the productivity of the ocean is already turning up new and significant information. Scientists from Woods Hole have equipped an aircraft with a carbon dioxide analyzer and have made many measurements of the change in concentration of carbon dioxide with altitude and also along great horizontal distances.

At six island stations in the Atlantic Ocean, observations were made of sea level and ocean waves. Lamont scientists report that storm waves may be useful in forecasting impending severe weather conditions. They have also observed some anomalous changes in sea level and have made important observations on the nature of waves of various periods.

Arctic Ocean

Scientists from Lamont, Woods Hole, Air Force Cambridge Research Center and the University of Washington carried out oceanographic observations in the Arctic Basin at the two IGY stations A and B. Important topographic details were revealed of the floor of the Arctic Basin for the first time. Bottom photographs were obtained and it was found, for example, that rocks and pebbles are scattered along the sea floor at great distances from land. Some of these rocks were recovered by letting the drifting station drag a wire net across the bottom. When the rocks were inspected they were found to be similar to rocks in north Greenland and Ellesmere Island. Is is postulated that icebergs, even pack ice, have rafted these rocks from the edges of the Arctic Basin into its interior. The distribution of rocks and their time of deposition, determined from examining bottom photographs which reveal how much new sediment was deposited on them, is a new tool for understanding past circulation of this ocean. Some of the sediment cores obtained in the Arctic Basin reveal clues as to the nature of climatic changes during the recent glacial epochs.

Along the arctic coast of Alaska and out to sea for a distance of about 250 miles, Scripps Institution scientists have been making continuous records of tides, and have been studying the bottom geology and the circulation of the water.

A varied biological program was carried out and the biologists examined the underside of the pack ice using "frogman" equipment. Many samples were collected for study at home laboratories.

The United States made a great contribution to exploration of the oceans when two atomic powered submarines were successfully navigated under the arctic ice pack. Although not a part of the IGY program, I thought I should call to your attention the possibilities and implications of this work. These vessels are uniquely adapted to research work in such a region, and we look forward hopefully to their peaceful utilization in the gathering of basic scientific data in otherwise almost completely inaccessible regions of the earth.

Antarctic oceanographic observations

Ships of the U.S. Navy Task Force 43 were able to undertake some oceanographic observations during the expeditions each year to the Antarctic. The U.S. Hydrographic Office has published several reports on this work. This Office has also published a most important oceanographic atlas of the polar seas, the first volume of which is devoted to Antarctica. Hydrographic Office oceanographers on board the Navy vessels collected marine specimens for the National Museum, occupied hundreds of oceanographic stations and took many core and bottom samples. Important observations were also made of the antarctic convergence and several detailed profiles across the convergence were obtained.

Interpretation and implications of the IGY oceanography program

The basic interpretation of the vast quantities of data will take several years. However, a good start is being made through the supplemental funds recommended in 1958 by this Committee and now allocated by the U.S. National Committee for the IGY to the various institutions participating in this program. In the Atlantic Ocean, we will have a much better idea of the distribution of water masses and of the circulation of water around the edges of the basin and the deep waters from the polar to the equatorial regions. The tracing of various radioactive isotopes, natural and artificial, is already telling us something of the way in which surface waters mix with deep waters. The extensive seismic explorations are yielding important new information on the structure of the earth crust and the changes in the earth crust leading to formation of undersea mountain ranges and deeps. In the Pacific the great equatorial current systems pose important problems to oceanographers studying the general circulation of the ocean. The vast amount of water transported by surface and subsurface currents must be accounted for and our present theory must be examined in the light of these new data. We know that the water of 1,000 Mississippi Rivers cannot just disappear near the Galapagos Islands. But what happens to all the water? In what way does it have effects on the airmasses over the ocean, and on conditions in the great fishing areas in the Pacific? Where does all the water come from in the western Pacific? An even more interesting question is, Why is there a great countercurrent north of the equator and not a similar one symmetrically placed south of the equator? Scripps Institution of Oceanography is already planning a cruise in 1959 to return to these most interesting currents and to learn more about them. Of equal importance to man and his use of the oceans and his dependence on the ocean for food is the appearance and disappearance of warm surface waters in the Pacific. The changing water temperature has an important effect on the appearance and disappearance of economically important fish populations.

We have just begun to study properly the waters of the Arctic Basin and their relation with the Pacific and Atlantic Oceans. The Arctic Basin is almost landlocked with very low exchange of water through the Bering Strait and Davis Strait. Most of the water is exchanged in the area of east Greenland, to Iceland, northern Scotland, and Norway. There may be a most significant relation between the exchange of Atlantic and Arctic Basin waters which may be the product, perhaps even the cause, of the great ice ages of the past million years. The internal circulation of the Arctic Basin is also important, as this in turn affects the distribution of pack ice and the navigability of the waters around the edges of the basin.

The Antarctic Ocean is the only place in the world where circumpolar currents can exist without being deflected or stopped by land masses. The antarctic circulation undoubtedly plays a critical role in the antarctic weather, which in turn is one of the most important factors in the circulation of the atmosphere, certainly in the Southern Hemisphere.

The scientific implications of the IGY program are just beginning to be understood and in the next few years, as the scientists continue their extensive study of this data, we will understand more fully what scientific contribution the IGY has made. However, even now we can say that the IGY, irrespective of the individual scientific discoveries, is playing a most significant role in immediate and long-range planning. The IGY program has shown us (i) how much we can do in terms of present resources of scientific manpower and equipment, (ii) indicated what directions our immediate and future research might most profitably take, and (iii) has furnished us with clear ideas as to how we will have to enrich our resources of scientific manpower to accomplish the work that we are convinced should be done by the United States within the next decade.

II. International Cooperation

Last year, I informed the committee that oceanographers have been so inspired by the planning and early results of the IGY that a special new international committee was organized by the International Council of Scientific Unions. A great scientific symposium on recent oceanographic work will be conducted next September in New York, where oceanographers from all over the world will gather and exchange information and ideas.

The United Nations Educational, Scientific, and Cultural Organization, in its natural sciences program, has recently begun to place emphasis on the international development of the sciences of the sea, especially in regions where there has been little emphasis in the past. To guide this work, which is being carried out in cooperation with the Food and Agriculture Organization of the United Nations, UNESCO has established a nine-man International Advisory Committee on Marine Sciences. At the same time, the International Council of Scientific Unions, having in mind the successful planning of the IGY program, has established a Special Committee on Oceanic Research, with responsibility for developing an international cooperative program of fundamental research.

UNESCO's marine science program

The amount of funds available to UNESCO for promotion of scientific research is not comparable to the expenditure of any major country for this purpose. Consequently, its activities in the sciences must be very largely confined to the planning of international action, facilitation of the making of contacts among scientists of different countries, and exchange of ideas and information.

In accordance with the advice of the International Advisory Committee, the principal objective of UNESCO's marine sciences program is to encourage development of these sciences in regions where little is known about the oceans or the organisms that they contain and where there is economic and social need for increasing the harvest of food from the sea. Up to the present, UNESCO has taken steps toward the realization of this objective by providing (i) fellowships for advanced training of scientists from these regions at major centers of marine research; (ii) intensive training programs, lasting from a few weeks to a few months, for technicians and field workers within such a region; (iii) intraregional conferences that give local scientists opportunities to discuss their common problems; (iv) international symposia, conducted by scientists of wide reputation on general topics in the marine sciences, in countries or regions where these sciences have been little developed; and (v) funds to make possible the joint planning of cooperative observational programs. A modest start has been made in all these directions.

One of the most important proposals made by the International Advisory Committee has been that an international oceanographic ship should be commissioned and operated, either by UNESCO itself, under contract, or by a group of countries in accordance with the pattern for international operation of research facilities set by CERN (Comité Européen de Recherche Nucléaire). This ship would be used primarily in such a little-known area as the Indian Ocean and could serve both for obtaining scientific information and as a training ship for younger scientists in the bordering countries.

A third area of activity has been that of furnishing scientific assistance to other United Nations organizations; for example, a report on sea and oceanic disposal of atomic wastes has been prepared.

UNESCO, because of its broad educational and scientific responsibilities, can draw the attention of the governments of its member states to the importance of marine research without overemphasizing the prespects of immediate useful results. It can stress the longer-range possibilities and the value of the marine sciences as a means of introducing science for its own sake.

Finally, UNESCO, as an intergovernmental organization, can, by various means, encourage the member States to maintain policies favorable to international scientific work on the oceans. Examples are the facilitating of exchange of scientists between research vessels and laboratories of different countries in the face of political difficulties, the relaxing of customs regulations and of other barriers to the exchange of scientific instruments for use in international cooperative marine investigations, and the maintaining of freedom of scientific research on the Continental Shelf and offshore waters.

Special Committee on Oceanic Research

The Special Committee on Oceanic Research (SCOR) of the International Council of Scientific Unions consists of 15 members. Six members were nominated by the International Council of Scientific Unions, four by the International Union of Geodesy and Geophysics, two by the International Union of Biological Sciences and one each by the International Union of Pure and Applied Physics, the International Union of Pure and Applied Chemistry, and the International Geographical Union. This committee held its first meeting at the Woods Hole Oceanographic Institution from August 28–30, 1957 and its second meeting in Paris from September 26–27, 1958. Members present at both meetings were: A. F. Bruun, Denmark; G. Bohnecke, Germany; L. R. A. Capurro, Argentina; G. E. R. Deacon, United Kingdom; M. N. Hill, United Kingdom; C. O'D. Iselin, United States of America; N. B. Marshall, United Kingdom; Y. Miyake, Japan; H. Mosby, Norway; N. W. Rakestraw, United States of America; R. Revelle, United States of America; E. Steeman Nielsen, Denmark; and L. Zenkevitch, U.S.S.R.; Prof. Y. Le Grand of France, and Dr. N. K. Pannikar of India were unable to attend. Representatives of FAO, UNESCO, UGGI, UAT, WMO, and interested national organizations in France, Germany, Finland, Italy, and Sweden were present at the Paris meeting.

The committee took as its first task that of defining the needs for further international scientific cooperation in the marine sciences. It is clear that, as in other sciences, a very large part of the pioneering research and new ideas concerning the oceans must come from individual scientists or small groups working independently. A broadly based international organization can be helpful, however, in several ways. It can serve as a sounding board to emphasize the economic and social importance of greater knowledge of the oceans and thereby assist marine scientists in different countries to obtain support for their work. By arranging wide dissemination of ship-operating schedules, it can help scientists to participate in cruises or to obtain desired data and collections. By pointing out areas and kinds of observations where work needs to be done, it can encourage more efficient use of research vessels. It can facilitate the exchange of techniques, personnel, samples, and data. By sponsoring or encouraging discussions of ocean research problems at national and international scientific meetings, it can help enlist scientists from other fields. It can arrange for coordinated work at sea by research vessels and shore observatories of different countries in attacking problems where a wide network of observations is needed. It can serve as a mechanism for the standardization and intercalibration of techniques and instruments, and can arrange for the introduction of techniques newly developed in one country or laboratory to other scientific groups elsewhere in the world.

The committee considered that its principal objective should be to encourage and coordinate an international program of observation and measurement in the deep ocean. One point of this program would involve an intensive effort to understand the relationships between the dynamics of the upper water layers and the populations of plants and animals. Another would be the study of the region below the thermocline down to the greatest depths of the sea, and beneath the sea floor. Because so little is known about this region, its investigation will be, to a large extent, a task of widespread exploration. Such exploration must proceed hand in hand with theoretical studies and development of new techniques by individual scientists, and must supplement rather than interfere with their work.

In making a decision to concentrate its program in the deep oceanic regions, the committee recognized the necessity of geophysical and geological studies of the earth beneath the sea in elucidating the structure and history of the earth. With regard to the waters and their contained organisms, it emphasized three long-range problems that may be critical to the future welfare of mankind.

The first of these concerns the use of the deep sea as a receptacle for the waste products of our industrial civilization. This may be a particularly important problem in the future, when very large quantities of poisonous radioactive wastes will be produced by the industrial use of atomic power. We need to know whether we can dispose of at least part of these wastes in the deep sea or whether the oceanic circulation or the vertical movements of the fauna will result in too rapid a transport of dangerous material to levels in the sea from which some of the world's food supplies are derived.

The second problem concerns the oceans as an important source of protein food for many of the world's peoples. With the growth of populations, man's

need for food from the sea may be expected rapidly to increase. The living resources of the oceans are by no means infinite and, like the land, different parts differ widely in fertility. The fertile areas are those where nutrient trace substances, essential for plant life, are brought up from the deep waters. To obtain the maximum harvest, the processes by which this occurs must be elucidated.

The third problem is perhaps the least well understood of the three. It concerns the role of the oceans in climatic change. During the last 50 years the average temperature over eastern North America and northern Europe has markedly increased, while elsewhere prolonged droughts have destroyed the work and hopes of decades. Will this trend continue over the next 50 years, or will it be reversed? Because we do not have sufficient understanding of the processes that control climate, we are quite unable to make a forecast. Nevertheless, a prediction of future climate would be of inestimable value to society.

The waters of the ocean may play an important role in changing climates. For example, an excess of heat from the sun can be stored in the deep water and slowly released over many years to warm the air. Likewise, the amount of carbon dioxide in the air controls, at least to some extent, the average air temperature and the loss of heat from the earth. Any change in atmospheric carbon dioxide, for example, by addition from fossil fuel combustion, may be damped or modified by the absorption of carbon dioxide in the ocean waters.

For all three of these problems greater knowledge is required of the rate and character of the exchange between the deep and surface waters of the oceans. It is only within the last few years that we have been able to make an effective attempt to gain such knowledge through theoretical analysis of the thermodynamics and hydrodynamics of the oceans, laboratory and field experimentation, and the development and field use of new techniques.

Among these new techniques are: the use of natural radioactive substances occurring in the water, such as radiocarbon and tritium, to trace the paths of motion and the mixing of the waters; means for the direct measurements of the deep currents, by following free-floating neutrally buoyant buoys or by using deep current meters (for these it is necessary to maintain a fixed reference position and this can now be achieved by tautly anchoring a subsurface buoy to the sea bottom); measurement with a new order of precision of the salt content of the water, allowing the salt to be used as a tracer of the water movements; measurement of the heat flow from the interior of the earth into the deep water, so that the heating of the water can be used as an index of its time of passage over the bottom; the possible introduction of relatively large amounts of artificially radioactive substances, of the order of tens of thousands of curies or more, into deep ocean areas and the measurement of the dispersion and transport of this material by the deep currents; detailed biological, chemical, and physical studies of the variations in the sediments of the deep sea floor, to decipher past changes in the water conditions; new methods of high precision for determining carbon dioxide in the water and the air.

Deep sea exploraton, because it involves the use of relatively large and heavily equipped ships for long periods, is the most expensive kind of oceanic research. An adequate program of exploration is beyond the resources of any one country. Moreover, the total cost will be minimized through planned international cooperation in the use of ships and facilities.

Working groups of SCOR

Five working groups have been formed, each consisting of active research workers in particular fields.

1. *Radioactivity in the ocean.*—Primary objectives: standardization, intercalibration and exchange of information on analytical methods; coordination of worldwide oceanic measurements of artificial radioactivity; oceanic tracer experiments. Support for meetings of the working group should be sought from the International Atomic Energy Agency, FAO, and UNESCO.

2. *Carbon dioxide in the ocean and atmosphere.*—Primary objectives: assay of present concentrations in ocean and atmosphere and monitoring changes; study of exchanges between ocean, atmosphere and biosphere; use of carbon dioxide content and isotopic relationships to characterize water and air masses.

3. *Measurement of the productivity of the sea and of the standing crops of phytoplankton and zooplankton.*—Primary objetcives: to appraise and recommend methods for worldwide comparisons of organic productivity and standing crops.

4. *Physical properties of sea water.*—Primary objectives: to appraise the accuracy of present values of the physical constants and to encourage research leading to more accurate values. This is a joint working group with the Interna-

tional Association of Physical Oceanography. An international conference on the subject was recently held in the United States.

5. *International Indian Ocean expeditions.*—Primary objective: to plan and organize international cooperative exploration of the Indian Ocean. This is the major project of SCOR. The working group must meet as a whole or in part on several occasions and needs considerable financial support.

Continuation of IGY research in oceanography: The most immediate responsibility of SCOR has been to make recommendations about the continuation of the IGY oceanographic research during 1959. The following specific recommendations were made:

1. *Sea level spectrum.*—It is strongly recommended that the net of stations for sea level recording, supplemented by regular observations of temperature and salinity (density), established during IGY, be continued. Displacement of water from one area to another, changes of volume due to temperature and salinity changes, precipitation, evaporation, fresh water supply from rivers and other processes enter into a complex water balance problem, of interest not only to marine sciences, but also to geodesy, for which the sea level measurements are key values of great importance.

2. *Long waves.*—A continuation of the international program of longwave recording, on the other hand, does not appear to be much needed at the moment. Difficulties in taking and in interpreting these observations seem to be due to imperfect instrumentation and to local effects which often dominate the wave spectra. It, therefore, appears more desirable that interested individuals and laboratories continue their studies of these phenomena and in particular of the problems of methods.

3. *General circulation of the ocean.*—The committee will make a detailed appraisal of the requirements for future work. It considered that work along the following lines should be continued in 1959.

(*a*) Expeditious publication of data obtained during the IGY, particularly those from the Indian Ocean.

(*b*) Direct measurements of currents at all depths; for the deep circulation, it is particularly important to study the western boundary currents, e.g., below the Gulf Stream and the Brazil current and in the Tonga-Kermadec region.

(*c*) Studies of the "age" of the deep water. C_{14} samples are needed at all depths in high latitudes.

(*d*) Studies of mining across the thermocline. Concentration of artificially radioactive substances above and below the thermocline should be measured and studies made of the possible effects on interpretation of the measurements of biological transport across the thermocline.

(*e*) Continuation of the ICES "Polar Front" program with particular reference to the overflow of water from the Arctic Basin to the North Atlantic Ocean.

(*f*) Studies of the equatorial current in the West Pacific. It is hoped that Japan, in cooperation with the U.S.S.R., if possible, will undertake multiple ship operations.

(*g*) Studies of water motion near the deep sea floor with the help of photographs and direct observations from the bathyscaphes.

(*h*) Studies of the deep circulation of semienclosed seas such as the Black Sea, Baltic Sea, and the deep basins of the Caribbean Sea.

4. *Carbon dioxide in ocean and atmosphere.*—We seem to be well on the way toward determining the present average concentration of carbon dioxide in the atmosphere, by means of a program of sampling by airplane, as well as by the results from a number of fixed stations where intermittent or continuous analyses are being made under conditions as favorable as possible for establishing average values.

We are still very ignorant of the rate and extent of the exchange of carbon dioxide between the atmosphere and the ocean. Further study of the conditions of equilibrium between the atmosphere and the sea is necessary and more extensive field work at sea must be undertaken to ascertain the actual relation between the atmospheric carbon dioxide and that in the sea surface, and the dependence of this relation upon meteorological conditions and the biological and other activities in the water. It is important that this phase of the whole study be continued.

The study of the synoptic pattern of carbon dioxide in the atmosphere may have considerable importance to meteorology and certainly has important relations to the primary objective, determining the present average level of atmospheric carbon dioxide. This study seems to be satisfactorily organized at present,

and its support beyond the IGY assured. This support must not be allowed to fail.

5. *Geophysical exploration under the sea floor.*—What is primarily needed is the use of existing methods; e.g., measuring heat flow through the ocean floor, and seismic exploration, by more countries, in order to provide a wider network of observations.

Formation of national committees

It was reported that Japan, U.S.A., and U.S.S.R. have already designated national committees as correspondents to SCOR. A draft letter has been prepared inviting other national scientific bodies to take similar action. This letter will also request financial support for the international planning activites and admnistration of SCOR. Advice will be sought from ICSU.

International Oceanographic Congress

The Committee enthusiastically agreed to sponsor, together with UNESCO and the American Association for the Advancement of Science, the International Oceanographic Congress to be held at the United Nations, August 31 to September 11, 1959. ICSU will be requested to invite its adhering bodies in the different countries to be represented at this Congress and especially to send young scientists. In addition, countries will be asked to send their research vessels, if possible.

International Indian Ocean expedition

During the past year members of SCOR have been much encouraged by the enthusiasm with which scientists have received the proposal made by the Committee at its Woods Hole meeting, that there should be an international cooperative attack on the scientific problems of the Indian Ocean. Marine physicists are enthusiastic about the opportunity to study the response of density layering and currents to the changing monsoon winds; marine biologists are keenly interested in the high and varying productivity of different parts of the Arabian Sea, where there are shifting populations of important food fishes and frequent catastrophic mass mortalities of fish; geologists and geophysicists have emphasized the lack of knowledge of the submarine topography, sediments, and structure of this vast region.

Partly because of SCOR's emphasis on the problem, U.S.S.R. and the U.S.A. vessels have already undertaken preliminary explorations in the Indian Ocean during the IGY and further expeditions are being planned for 1959–60. The Committee felt strongly that the climax of this work should be an international collaborative effort with many ships during 1961–62.

It is anticipated that UNESCO will play a major role in enabling scientists and students from the countries bordering on the Indian Ocean to take an active part in this series of simultaneous expeditions. The expeditions would thus serve not only their primary purpose of research and exploration, but also would have a lasting effect in encouraging and developing the marine sciences and fisheries in those countries.

It is estimated that at least 16 ships from 11 different countries could be enlisted. Each research vessel would spend approximately 8 months at sea. The combined scientific party on all the ships would total around 125 persons; at least 25 of these might come from countries bordering the Indian Ocean area, and it would be desirable to give many of the latter a year's prior training in centers of advanced oceanic research. At least 100 scientist years would be required for working up the results.

A program of international cooperation in deep sea research cannot be carried out successfully without the enthusiastic support of existing international marine science organizations. Every effort will be made to utilize their facilities and procedures.

Ideally the total expenditure for a year-long program of multiship exploration would be about $4 million, largely for ship costs. Half of this amount could come from the normal operating funds for ships and marine research laboratories of the participating countries, but additional funds totalling $2 million should be raised. Although this is a large sum, it is small in comparison with the results that are expected and with the amounts spent in other kinds of international scientific collaboration. Important gains would be realized with a carefully planned series of expeditions each consisting of one or two ships or with a limited program for several ships, but the overall value of much of the work will be greatly increased if a large number of ships operate together. The committee,

therefore, urges that as many countries as possible should participate in the plan for 1961–62.

Additional projects

SCOR and its working groups are investigating what can be done by more international cooperation (supplementing that of other international associations) in the following ways:

1. *Oceanic populations and productivity.*—Except in a few cases it is not yet possible to assess the sizes of marine populations at different trophic levels, or the biological productivity on a worldwide basis. Quantitative data are absent or inadequate in many regions, while in others inter-calibration of collecting and assay methods is necessary.

2. *Life histories and distributions of important and interesting oceanic species.*—Collections of all stages of the life history should be made by ships of many countries in accordance with problems defined by specialists. To enable these scientists to determine the factors which govern the distribution, careful environmental data should be obtained for each sample.

3. *Study of convergences and divergences.*—The relations between abundance of organisms and zones of convergence and divergence are not clear and should be studied on a worldwide basis.

4. *Appraisal of the status of the marine sciences.*—Through its national committees SCOR will attempt to compile information on the status of marine sciences in all countries, including financial support, numbers of scientists and technical personnel, research vessels, and amout of emphasis on different objectives.

5. *The best use of existing facilities.*—Many creative marine scientists do not now have sufficient opportunity for work at sea. Others who could be enlisted for oceanic investigations do not know of the existing facilities. The Committee believes that this situation can be greatly improved by international exchange of information on ships' schedules and availability, and will attempt such exchanges through its secretariat.

6. *Oceanic surveys.*—Systematic surveys of the deep sea floor, and of physical properties of the deep water are very inadequate and are greatly needed. These should be carried out by the national surveying organization of the different countries. Standards of accuracy need to be established. This task is too great for any one country, but is well within the capabilities of the major maritime countries working together with a coordinated plan.

7. *Cooperation in tracer experiments.*—During future years when the present difficulties of making measurements at depths of several thousand meters and of obtaining accurate positions on the high seas have been sufficiently overcome, tracer experiments using large quantities of artificially radioactive material to study deepwater movements and biological transport should be undertaken in appropriate deep sea areas. These will involve very careful international planning and procedures.

Budget for administration of SCOR

Commitments and expenditures for 1958 total about $4,500—almost entirely for the Paris meeting. For 1959 approximately $23,000 are required as follows:

SCOR meeting in New York	$8,000
Administrative assistance and stenographer for SCOR secretary	5,000
Meetings of 2 working groups	10,000
Total	23,000

III. Ten-Year U.S. Program Recommended by the National Academy of Sciences

Man's knowledge of the oceans is meager indeed when compared with their importance to him. Recognizing that neglect in this area of endeavor might well result in our being placed in a precarious position from the scientific, technological and military points of view, the National Academy of Sciences-National Research Council decided in 1957 to form a Committee on Oceanography. In May of that year President Detlev Bronk appointed Harrison Brown, professor of geochemistry at the California Institute of Technology, Chairman of the Committee. The Committee itself was formed during the following months and its first meeting was held in November 1957. The members of the Committee are:

Harrison Brown (Chairman), California Institute of Technology, Pasadena, Calif.
Maurice Ewing, Lamont Geological Observatory, Columbia University, Palisades, N.Y.
Columbus O'D. Iselin, Woods Hole Oceanographic Institution, Woods Hole, Mass.
Fritz Koczy, Marine Laboratory of the University of Miami, Miami, Fla.
Sumner Pike, Lubec, Maine, formerly Commissioner, U.S. Atomic Energy Commission.
Colin Pittendrigh, Department of Biology, Princeton University, Princeton, N.J.
Roger Revelle, Scripps Institution of Oceanography, La Jolla, Calif.
Gordon Riley, Bingham Oceanographic Laboratory, Yale University, New Haven, Conn.
Milner B. Schaefer, Inter-American Tropical Tuna Commission, La Jolla, Calif.
Athelstan Spilhaus, Institute of Technology, University of Minnesota, Minneapolis, Minn.
Richard Vetter (Executive Secretary), formerly with the Geophysics Branch of the Office of Naval Research, Washington, D.C.

The work of the Committee was made possible by the sponsorship of several Government agencies, all of which have interests in the oceans: Atomic Energy Commission, Bureau of Commercial Fisheries, National Science Foundation, and the Office of Naval Research.

The Committee has made a survey of the present status of the marine sciences in the United States. It has attempted further to assess the major problems of operations, administration, and funding in this area and to evaluate the probable needs for oceanographic knowledge in the years ahead. On the basis of its findings, the Committee has drawn up a series of recommendations which, if followed, can result in a strengthening of the marine sciences during the next 10 years to a level which is consistent on the one hand with the assessed needs, and on the other with limitations such as the rates at which ships and laboratories can be built and new oceanographers can be trained. It should be stressed, however, that the Committee considers its recommendations minimal ones. Action on a scale appreciably less than that recommended will jeopardize the position of oceanography in the United States relative to the position of the science in other major nations, thereby accentuating serious military and political dangers, and placing the Nation at a disadvantage in the future use of the resources of the sea.

In considering the importance of the problems involved, the Committee concluded that the seas present a challenge to man which in magnitude approaches that of space. At least we have been able to observe the moon, planets, and stars directly with our telescopes. But the ocean depths, shrouded in darkness, have been obscured from our view. We know less about many regions of the oceans today than we know about the lunar surface. Yet we have learned enough to know that major features of the ocean floor—35,000-foot-deep trenches; 2,000-mile-long fracture zones; flat-topped undersea mountains; broad ocean long ridges; abyssal plains as flat as a calm sea—are uniquely different from anything either on the surface of the moon or on the land surfaces of earth. How and when were these features formed and why are they so different? An answer to these questions is essential if we are to decipher the history of our planet and its sister planets. Part of the answer lies in the records of ancient earth history locked in deep sea sediments; part will come from an intensive study of the rocks under the ocean. These studies, combined with studies of the waters and the living creatures of the sea, will also tell us much about the origin and evolution of life on earth.

During the last few years, four great subsurface ocean currents—rivers in the depths of the sea 1,000 times greater in flow than the Mississippi—have been discovered using newly developed current measuring techniques. We suspect that others exist and we need to know where the waters come from and where they go.

On the practical side, the problems to be solved concerning the oceans are at least as urgent as those of space. How many fish are in the sea? No man knows, nor do we know what determines the numbers of fishes in different regions, the quantities of plant and animal material on which they feed, or what could be done to increase these numbers. We must learn these things if we are to help solve the increasingly acute problems of providing animal protein food for the growing numbers of underfed people in the world. Given more study, man can economically harvest considerably more food from the seas than is now

possible. Considering the position of the United States in the community of nations, it seems appropriate, even essential, that we lead the way in this respect.

About a third of the energy of sunlight is used to evaporate sea water. This evaporation and the subsequent condensation are the primary means by which solar energy is absorbed in the atmosphere. There is good reason to believe that changes in the location where interchange of matter and energy takes place between sea and air affect persistent weather patterns. We know that the average weather conditions we call climate can change over a few decades, and we suspect that changes in the storage of gases and heat in the oceans will profoundly influence the process. Studies of the mechanisms of interchange between the air-sea boundaries of regions where intense interchange occurs and of the slow mixing between the ocean deeps and the surface which controls storage of heat and gases are essential for further understanding, hence for prediction and possibility of control.

From the point of view of military operations there is no comparison between the urgencies of the problems of the oceans and those of outer space. The submarine armed with long-range missiles is probably the most potent weapon system threatening our security today. It seems clear that the pressures of establishing effective bases, and of protecting ourselves from attack, are relentlessly driving us into the oceans.

The problems involved in military operations in the sea are enormous. We will not be able to navigate under the oceans with adequate precision until our knowledge is greatly expanded. Nor will we be able to detect submerged submarines efficiently unless we learn far more about the ocean depths than we now know. We will not be in a position to negotiate an adequate international submarine control and monitoring system until we have the ability to make the oceans transparent so that we can track all submarines in the oceans, both our own and all others. To accomplish this, we must place greater national emphasis on research in the marine geophysical sciences, on surveys of the ocean background against which tracking must be accomplished, and on the development of effective devices to achieve such oceanwide surveillance. The Committee's recommendations constitute an essential first step in these directions.

The Committee made five general recommendations concerning basic research, oceanwide surveys, applied research, allocation of support responsibility among Federal agencies, and the role of private foundations, industry, and the States.

1. *Basic research.*—The key to the growth of oceanography in the United States lies in basic research—research which is done for its own sake without thought of specific practical applications. The very nature of basic research is such that the problems which will be attached and the results which will be obtained cannot be predicted. The very nature of applied research is such that its success depends upon the size of the reservoir of fundamental knowledge upon which it must draw. The rate of progress in the applied marine sciences will be determined in the long run by the rate of progress in the basic marine sciences.

The Committee has concluded that both the quantity and quality of basic research in the marine sciences can and should be increased substantially during the years ahead. Specifically the Committee recommends:

The U.S. Government should expand its support of the marine sciences at a rate which will result in at least a doubling of basic research activity during the next 10 years.[1]

It should be emphasized that doubling the basic research activity will require more than doubling the total expenditures.

A large part of the deliberations of the Committee were devoted to discussions of the conditions under which basic research can flourish. First and foremost, progress depends upon the interests, experience and creative imaginations of individual scientists. But the individual scientists does not work in a vacuum. He must have instruments and facilities. He must live in an atmosphere which is conducive to creative activity. These necessities in turn give rise to problems involving marine research laboratories—problems of leadership, financial stability, flexibility, growth, academic associations, and physical facilities.

2. *Oceanwide surveys.*—Not only for research but in order to exploit and use the oceans we need more detailed knowledge which can only be obtained

[1] In 1958 about $23 million were spent by applied and basic oceanographic research. The basic research share of the total was not over $9 million. About $8 million of this, including the 1958 share of IGY expenditures, was Federal funds.

through systematic surveys in three dimensions. These surveys should include such features as depth, salinity, temperature, current velocity, wave motion, magnetism and biological activity. It is essential that these surveys be conducted on an oceanwide ocean-deep basis as quickly as possible. Our knowledge is now largely limited to waters 100 miles from shore and even here it is inadequate for present and future needs. Accordingly, the Committee recommends:

The increase in support of basic research should be accompanied during the next 10 years by a new program of oceanwide surveys. This will require a twofold expansion of the present surveying effort.

3. *Applied research and development.*—We believe that, on a long-range basis, basic research coupled with systematic ocean surveys are of paramount importance in solving a number of urgent practical problems involving military defense, the development of ocean resources and possible future increases of radioactive contamination of the seas resulting from the rapid development of atomic energy. However, research and surveys must go hand in hand with a vigorous and imaginative applied research and development program. Accordingly, the Committee recommends:

The United States should expand considerably its support of the applied marine sciences, particularly in the areas of military defense, marine resources and marine radioactivity.

4. *Proposed allocation of support responsibility among Federal agencies.*—The implementation of these general recommendations requires action upon a number of broad fronts. More marine scientists must be educated. Additional ships and shore facilities must be built. New instruments and techniques must be developed. International cooperation in the marine sciences must be strengthened.

To achieve these aims in the next 10 years will necessitate many agencies of the Federal Government working together both in planning and in providing moneys.[2] Taking into account the relative degrees of interest and importance of oceanography to individual agencies, the Committee recommends:

The Navy and the National Science Foundation should each finance about 50 percent of the new basic research activity except ship construction. The Navy should finance 50 percent of the new research ship construction with the Maritime Administration and the National Science Foundation sharing the remainder. The Navy, through the Hydrographic Office, should finance 50 percent of the deep ocean surveys, while the Coast and Geodetic Survey should finance the balance. The Navy should sponsor completely all military research and development operations. The Bureau of Commercial Fisheries should finance the greater part of the recommended ocean resources program. The Atomic Energy Commission should finance the major part of the research dealing with the problems of radioactive contamination of the oceans. The National Science Foundation and the Office of Education should sponsor jointly the proposed program for increasing scientific and technical manpower in the marine sciences. Efforts aimed at fostering international cooperation in the marine sciences should be sponsored by the Department of State, the International Cooperation Administration and the National Science Foundation. Other agencies should take responsibility for certain aspects of the proposed program, particularly the Public Health Service, the Geological Survey and the Bureau of Mines.

5. *Support from non-Federal sources.*—Although the bulk of oceanographic research and survey work must of necessity be financed by the Federal Government, the value of State and private funds cannot be overestimated. Such funds are especially helpful for supporting initial exploratory basic research and for starting new laboratories. Accordingly, the Committee recommends:

Private foundations and universities, industry and State governments should all take an active part in the recommended program of expansion.

Education and manpower

1. In order to finance new faculty in oceanography at existing or new teaching centers, the U.S. Government should provide funds on long-term commitments. This Committee recommends that about $500,000 per year be appropriated for salaries and the equipment and indirect costs associated with such positions. This program could be operated through the Office of Education.

[2] One method suggested for developing more effective interagency cooperation is through the proposed Federal Council for Science and Technology. This Council is described in "Strengthening American Science," a recent report of the President's Science Advisory Committee.

2. In order to attract competent graduate students to the long and somewhat arduous schooling required of well-qualified oceanographers, it will be necessary to provide substantial long-term fellowships. It is believed that 80 fellowships should be supported on a 5-year basis and at an average stipend of $3,500 to $4,000 per student each year. This will produce 12 to 15 new Ph. D.'s per year (allowing a reasonable attrition factor) at an annual cost of about $300,000. This would provide approximately one-third of the student support that will be needed in order to double the number of oceanographers at the Ph. D. level during the next 10 years.

It is desirable that fellowships permit students to attend more than one university. This can provide students with well-rounded educations in all branches of oceanography without each university having to provide a full curriculum. Such a program should be handled through the National Science Foundation.

New ships for research, development, and surveying

1. A shipbuilding program should be started aimed at replacing, modernizing and enlarging the number of oceangoing ships now being used for research, surveying, and development. Specifically in the period 1960–70 the research, development, and survey fleet should be increased from its present size of about 45 ships to 85 ships. Taking into account the replacement of ships which must be retired during the next decade, this means that 70 ships should be constructed at a total estimated cost of $213 million.

2. The size ranges recommended for new oceangoing ships are about 500 tons, 1,200 tons and 2,200 tons displacement.

3. The conversion of vessels, which were originally designed for other purposes, into research, development, or survey vessels is to be discouraged. Such conversions are generally uneconomical.

4. The recommendations for the construction of ships for specific purposes (basic research, military research and development, oceanic surveys, resources and fisheries) are given in table 1.

5. The recommended size distribution for new ships is given in table 2.

6. The Navy should provide about 50 percent of the financing for the construction of new ships for basic research, all of the financing of new ships for military research and development, and 50 percent of the financing for new ships for oceanic surveys. The Coast and Geodetic Survey should provide 50 percent of the financing for the construction of new ships for oceanic surveys. The Bureau of Commercial Fisheries should finance the construction of all of the new ships for marine biological resources and fisheries studies. The National Science Foundation and the Maritime Administration should each provide about 25 percent of the financing for new ships for basic research.

7. Estimated capital costs by year and by agency are given in table 5, based upon the assumption that a 500-ton ship will cost about $1.65 million, a 1,200–1,500-ton ship will cost about $3.80 million and a 2,000-ton ship will cost about $5 million.

8. The Maritime Administration should be consulted in the designing of all ships paid for from public funds and used for marine studies.

9. Research ships operated by private institutions like those operated by the Navy, Coast Guard, and Coast and Geodetic Survey should be exempt from those existing legal requirements for living accomodations, safety and the licensing of crews, which are practical and sensible only on large (3,000 tons) merchant ships.

10. All noncombatant surface ships used for research, development or surveying should be operated by the laboratory or agency directly concerned and should have civilian crews.

10-YEAR PLAN FOR INCREASING THE U.S. FLEET OF OCEANOGRAPHIC SHIPS

TABLE 1.—*Function of ships*

	Research	Military research and development	Survey	Resources and fisheries	Total
Present fleet	11	9	18	7	45
To be replaced	5	9	9	7	30
Still operational in 1970	6		9		15
Additional new construction	11	11	11	7	40
Total construction	16	20	20	14	70
Total fleet in 1970	22	20	29	14	85

TABLE 2.—*Recommended size distribution of new ships*

	Research	Military research and development	Survey	Resources and fisheries	Total
500 tons	5	10	4	12	31
1,200–1,500 tons	9	6	11	2	28
Larger than 2,000 tons	2	4	5		11
Total	16	20	20	14	70

11. In most cases the annual costs of operating vessels for basic research by non-Government laboratories should be paid for separately from the other expenses of research, for example, through a long-term facilities contract distinct from any research contracts.

12. The costs of ship operations paid by the Federal Government should be subdivided as follows: the Navy should pay for 50 percent of the operational costs of ships used for basic research, all of the operational costs of ships used in military research and development and 50 percent of the operational costs of ships used for oceanic surveys.

The Coast and Geodetic Survey should pay for 50 percent of the operational costs of ships used for surveys. The Bureau of Commercial Fisheries should pay for the operations of ships used for resources and fisheries studies. The National Science Foundation should pay for 50 percent of the operational costs of ships used for basic research.

13. Estimated costs of ship operations, both by function and by agency, are given in tables 6 and 7.

Shore facilities for basic research

In order to derive the maximum knowledge from observations and collections made at sea, it is estimated that 60 technical persons must be available for the average ship involved in high seas research activity. Most of these persons are involved in land-based activities which require laboratories and associated facilities.

1. It is recommended that for every additional oceangoing research ship put into operation, an average investment of $1.5 million be made for essential shore facilities. These costs should be divided between the Navy and the National Science Foundation.

2. It is estimated that the costs of research other than ship operations will average about $1.2 million per ship per year. The committee recommends that Federal funds for this purpose be divided between the Navy and the National Science Foundation.

Oceanwide surveys

1. The committee recommends that for every new survey ship put into operation an investment of about $0.75 million be made for essential shore facilities.

2. It is recommended that an average of $0.75 million be allocated each year for the operation of shore facilities for each new survey ship placed in operation.

These costs should be divided between the Navy and the Coast and Geodetic Survey.

3. Consideration should be given to conducting some aspects of the survey program through contracts with commercial organizations and private institutions.

TABLE 5.—*Estimated capital costs for new oceanographic ships, by agencies*

[Millions of 1958 dollars [1]]

	Navy	Coast and Geodetic Survey	Bureau of Commercial Fisheries	National Science Foundation	Maritime Administration	Total
1960	23.95	5.45	3.30	1.65	5.45	39.80
1961	21.35	5.00	7.10	1.65	3.80	38.90
1962	20.90	7.60	7.10	5.00	1.65	42.25
1963	20.90	5.45	3.30	1.65		31.30
1964	19.25	5.00	3.30			27.55
1965	14.25	3.80	3.30			21.35
1966	7.60	3.80				11.40
1967						
1968						
1969						
Total	128.20	36.10	27.40	9.95	10.90	212.55

[1] Budget allocations have been assigned to the year immediately preceding that in which the ship is to be put into service.

TABLE 6.—*Estimated ship operations costs above present level, by function*

[Millions of 1958 dollars]

Year	Research	Survey	Resources and fisheries	Total [1]
1960				
1961	0.60	0.65	0.30	1.55
1962	1.20	1.30	.55	3.05
1963	1.80	2.00	.85	4.65
1964	2.35	2.60	1.15	6.10
1965	2.95	3.30	1.40	7.65
1966	3.55	3.90	1.70	9.15
1967	4.15	4.60	1.70	10.45
1968	4.15	4.60	1.70	10.45
1969	4.15	4.60	1.70	10.45
Total	24.90	27.55	11.05	63.50

[1] Excluding military research and development ship operations

TABLE 7.—*Estimated ship operations costs above present level, by agency*

[Millions of 1958 dollars]

Year	Navy [1]	Coast and Geodetic Survey	Bureau of Commercial Fisheries	National Science Foundation	Total [1]
1960					
1961	0.62	0.33	0.30	0.30	1.55
1962	1.25	0.65	0.55	0.60	3.05
1963	1.90	1.00	0.85	0.90	4.65
1964	2.47	1.30	1.15	1.18	6.10
1965	3.13	1.65	1.40	1.47	7.65
1966	3.72	1.95	1.70	1.78	9.15
1967	4.38	2.30	1.70	2.07	10.45
1968	4.38	2.30	1.70	2.07	10.45
1969	4.38	2.30	1.70	2.07	10.45
Total	26.23	13.78	11.05	12.44	63.50

[1] Excluding military research and development ship operations.

Engineering needs for ocean exploration

1. A vigorous program should be conducted for the development of manned submersibles that can operate down to and on the bottom of most of the ocean:

(*a*) An improved bathyscaphe using the best materials and techniques available should be designed and built immediately.

(*b*) Following up the recent commendable ONR action in bringing the bathyscaphe *Trieste* to the United States, it is recommended that funds be made available for a mother ship together with auxiliary equipment in order to make maximum use of this deep submersible.

(*c*) A continuous design and development program should be initiated aimed at building deep and mid-depth manned vehicles as the need arises and as the state of the art progresses.

2. The need for open-ocean manned research platforms which are stable, and which can remain in place so that time studies can be made, seems essential and the design for such a buoy should be started.

3. A major program should be supported aimed at developing and using anchored and drifting buoys for obtaining space and time coverage of ocean characteristics.

4. It seems likely that aircraft can be used effectively for some research and surveys on the open ocean, particularly for studies involving the joint problems of oceangraphy and meteorology. Nearly all laboratories will need single-engine planes; several will need twin-engined amphibious planes; some will need four-engined commercial-type aircraft.

5. Surface icebreakers are of limited value to arctic oceanographic research compared to properly equipped submarines. Efforts should be made to develop a submarine capable of breaking into and out of the ice.

6. Instruments should be developed for survey purposes which are more accurate, effective, and trouble free than those now in use. The techniques needed to use them more effectively should be developed. Specialized devices such as Loran C, inertial navigation equipment, gravity meters, and stable platforms should be made available for research as well as surveys as soon as possible.

7. A major program aimed at developing new high-seas engineering techniques should be started. Our abilities to handle heavy equipment and to conduct such operations as drilling and bottom sampling at sea limit our operations at present. Many of these difficulties would be appreciably lessened given proper effort. We have not included the very important problem of drilling to the Mohorivicic discontinuity in our budget because another academy group is studying this problem.

8. Machine aids to computation and data storage have much to offer and should be budgeted.

9. High pressure facilities to permit controlled physical and biological experiments in the laboratory are needed.

10. Efforts should be made to secure the active participation of private industry in the development and manufacture of new devices and instruments for oceanographic research and surveying.

11. The unpredictable aspects of new devices make difficult the formulation of an exact budget over a 10-year time scale. The Committee recommends that $48 million be allocated during the next 5 years. It further recommends that a minimum of $10.5 million be allocated each year thereafter. The cost of this program should be divided between the bureaus of the Navy and the National Science Foundation.

Radioactivity in the oceans

The widespread use of nuclear energy for peaceful or military purposes necessitates studies to determine the effects of radioactive contamination upon the oceans and the life therein. The Committee on Effects of Atomic Radiation on Oceanography and Fisheries in its report to the National Academy of Sciences made certain general recommendations concerning national policy in this area. Both the Committee on Oceanography and the Committee on Effects of Atomic Radiation on Oceanography and Fisheries believe that more specific and detailed recommendations can now be made.

1. A single agency should be given the overall responsibility and authority for regulating the introduction of radioactive materials in the oceans. Monitoring of disposal sites should be done by some agency other than the regulating agency. It is recommended that either the Coast and Geodetic Survey or the Public Health Service be made responsible for engineering studies in and near disposal areas, for routine monitoring of disposal areas and their surroundings

and for a continuing assessment of the effects on the environments of added radioactive materials.

2. Vigorous programs should be started for the purpose of determining the circulation and mixing processes which control the dispersion of introduced contaminants in coastal and estuarine environments and in the open ocean. These studies represent the major part of the proposed budget in this area.

3. A program should be pursued aimed at determining the inorganic transfer of radioactive elements from seawater to the sediments.

4. Studies should be made of the effects of living organisms on the distribution of radioactive elements introduced into the sea.

5. The genetic effects of radiation upon marine organisms should be studied.

6. A variety of biological field experiments should be conducted utilizing radioisotopes.

7. It is estimated that 10-year costs of new research in this area will be about $44 million.

Ocean resources

Lack of adequate understanding of the occurence, behavior, and potential harvest of fish and other marine organisms serves as a serious barrier to extensive economic development and utilization of marine biological resources. Existing knowledge is inadequate to evaluate the feasibility of creating a marine mineral industry.

1. The sea and its contents should be studied on a broad basis to enlarge our knowledge of its potential resources.

2. In order to elucidate the problem of population fluctuations of commercial fish stocks, which in large part is due to variable infant mortality, laboratory studies of the survival requirements of larval and juvenile stages of commercially important fish and shellfish are needed urgently.

3. There is an urgent need for facilities for studies of fish behavior in the laboratory under controlled conditions. This will require aquarium facilities of sizable physical dimensions.

4. Greater attention should be given to studies of the genetics of fish and other marine organisms.

5. Investigations should be made of the feasibility of adding nutrients to the euphotic zone of the sea in order to increase the productivity of marine organisms.

6. A program to investigate the possibilities of transplanting useful organisms from one region of the sea to another should be conducted.

7. More research is needed on the nature of the aggregations of organisms in the sea.

8. Biological surveys in the seas should be intensified, and programs should be initiated aimed at utilizing new devices such as unmanned buoys and the mesoscaph.

9. A data center for all oceanographic research should be established for the storage, routine processing, and "read-out" of such information as sea surface temperatures, currents, and meteorological data. This data center would not perform the functions of more specialized computing centers such as will be required for oceanographic forecasting.

10. There is a need for scientific, sociological, and engineering studies directed toward the wider utilization of marine products in protein-deficient areas of the world.

11. There is a pressing need for studies of the economic and legal aspects of commercial fisheries, especially in comparison with other industries, in order to provide a basis for national policy decisions.

12. A scientific study of salt water fishpond culture should be started, aimed at providing a basis for greatly increasing the efficiency and productivity of this industry and thereby increasing the protein food supplies in protein-deficient areas such as southeast Asia.

13. Many aspects of the potential mineral resources on the deep sea floor should be investigated. Such work should be supported through the Bureau of Mines.

14. An expanded program of estuarine research is recommended in order that we can make most effective use of this habitat of important resident stocks of food fish and shellfish and the nursery areas for other stocks which are later harvested from the open ocean.

15. Many lines of marine research depend upon precise definition of species. The study of species is centered in research museums which generally have been

supported very poorly. It is recommended that established museums having significant study collections be given financial support so that this kind of work can be carried forward.

16. It is recommended that a program on diseases and other toxic effects in the marine environment be established.

A 10-year operating budget of $78 million is proposed. The mineral resources investigation should be sponsored by the Bureau of Mines with the balance being supported by the Bureau of Commercial Fisheries through grants, contracts and in its own laboratories and with the assistance of other branches of the Department of the Interior. Programs involving international cooperation and technical assistance to other countries budgeted under this heading should be supported at least in part by the International Cooperation Administration and the State Department.

International cooperation

It is clear that, as in other sciences, a very large part of the pioneering research and new ideas concerning the oceans must come from individual scientists or small groups working independently. But international cooperation in work at sea is essential in several kinds of marine research and should also greatly facilitate surveys of the ocean floor and of the waters.

There is at present a high level of international cooperation among physical and chemical oceanographers of different countries resulting from the International Geophysical Year. This cooperation should be maintained and broadened throughout all aspects of the marine sciences, particularly including biology. To this end, the Committee recommends:

1. The United States through the National Science Foundation should give its proportionate share (amounting to perhaps $20,000 per year) of financial and other support to the Special Committee on Oceanic Research of the International Council of Scientific Unions. The Committee on Oceanography has been designated as the U.S. National Committee for this long-range cooperative program.

2. Grants should also be sought from foundations and governmental sources to support special projects such as the proposed year-long international expedition to the Indian Ocean by covering the increased expenses to United States oceanographic institutions and by making the participation of other countries possible. Special funds needed for the Indian Ocean project are estimated at about $2 million.

3. An intergovernmental conference of the maritime countries should be called, after suitable preparation, to discuss means by which the governments can cooperate in increasing man's knowledge of the oceans. Specifically, agreements should be sought regarding the means of carrying out oceanwide surveys, including allocation of responsibility to different countries, intercalibration of techniques, and free exchange of data. It would be expected that the United States proportion of this international responsibility for surveys would be about the same as its proportion of financial responsibility for support of United Nations agencies. This conference should be a first step toward the establishment of a World Oceanographic Organization; a United Nations specialized agency corresponding to the World Meteorological Organization.

4. In the study and conservation of the living resources of the sea, regional international organizations, such as the various international fisheries commissions, have proven effective.

In developing formal intergovernmental cooperation in the marine sciences, the Federal Government should give special emphasis to the establishment and adequate support of such regional organizations, and should seek to broaden their charter to allow an integrated research program on all aspects of a particular oceanic region.

5. In order to increase the effectiveness of cooperation between U.S. marine scientists and laboratories and marine scientists in other countries, the U.S. State Department should be prepared to assist positively, sympathetically and promptly in facilitating research ship operations and the exchange of information, persons, equipment and supplies.

6. The need for increased protein foods from the sea is especially urgent in underdeveloped countries. The International Cooperation Administration in its programs of technical assistance should give greater emphasis to marine resources surveys and to research projects and training programs in the marine sciences. The Federal Government should also encourage United Nations specialized agencies such as UNESCO and FAO in their efforts to aid underdevel-

oped countries to achieve greater utilization of marine resources. The funds needed for both these purposes have not been budgeted separately in this report but are included in the budget for ocean resources studies.

Budget and operations

Concerning the actual funding and operations, the Committee recomends:

1. A higher percentage of longer term funding must be made available in oceanographic research. Past funding has been inefficient, and has held back much longer term imaginative research. A reasonable portion (30 to 50 percent) of the annual operating budget should include 5-year money which is refreshed annually. Existing laws permit allocation of many funds on a 5-year basis. The military is accustomed to making long-term commitments of 5 to 10 years when they adopt a new weapons system and it is equally essential that they make long term commitments for research.

2. Administrators of research and laboratory directors must have a higher percentage (25 to 50 percent) of their funding free to spend on those good research problems which emerge without the benefit of planning.

3. Government organizations which presently fund or carry on extensive research and development in oceanography should continue to do so in the field of their special interests. For example, the Navy, the Atomic Energy Commission, and the Bureau of Commercial Fisheries all have their own important oceanographic problems. It is recommended that each bureau and organization sponsor and finance much of the research which it needs to meet the demands of its present and future objectives. Any duplication of effort which might be involved appears trivial compared to the value of insuring that scientists are in close touch with changing bureau problems.

4. There will still remain a need for a great deal of research which should be funded by the National Science Foundation. This agency should carry a much heavier portion of the long-term basic research in the Nation. A reasonable percentage of grants should be made to individuals and a reasonable portion should be allocated for long-term funding of institutional activities such as vehicles, facilities and major expeditions.

5. Foundations, States and industries should take an active part in the support of marine research. Their support is particularly valuable in new and unusual research programs, in filling technological gaps and through appropriate assistance insuring that private laboratories and academic groups do not become solely dependent on Federal assistance.

TABLE 17.—*Summary of budgets for new oceanographic activity* [1]

[Millions of 1958 dollars]

Year	Education and manpower	Ships	Shore facilities (research)	Shore facilities (surveys)	New devices	Radioactivity in oceans [2]	Resources	Total
1960	0.80	39.80	1.50	0.76	7.40	3.08	5.02	58.36
1961	.80	40.45	2.70	1.52	9.50	2.95	6.71	64.63
1962	.80	45.30	3.90	3.00	9.60	4.35	5.43	72.38
1963	.80	35.95	6.60	4.50	10.90	2.95	8.52	70.22
1964	.80	33.65	10.50	6.00	10.50	2.95	7.55	71.95
1965	.80	29.00	12.60	7.50	10.50	2.95	10.58	73.93
1966	.80	20.55	13.50	8.26	10.50	4.39	10.93	68.93
1967	.80	10.45	13.20	8.26	10.50	2.95	10.75	56.91
1968	.80	10.45	13.20	8.26	10.50	2.95	10.92	57.08
1969	.80	10.45	13.20	8.26	10.50	2.95	10.90	57.06
Total	8.00	276.05	90.90	56.32	100.40	32.47	87.31	651.45

[1] Not including special funds for basic research projects involving extensive international cooperation such as the proposed year-long international expedition to the Indian Ocean (estimated cost: $2 million).

[2] Plus ship time charges of $11.70 million to be subtracted from other categories.

TABLE 18.—*Summary of budget for new oceanographic activity, by agency* [1]

[Millions of 1958 dollars]

Year	Navy [2]	Coast and Geodetic Survey	Bureau of Commercial Fisheries	Maritime Administration	National Science Foundation	Office of Engineering	Atomic Energy Commission	Bureau of Mines	Total
1960	28.78	5.83	7.97	5.45	6.40	0.50	3.08	0.35	58.36
1961	28.83	6.09	13.86	3.80	8.35	.50	2.95	.25	64.63
1962	30.40	9.75	12.83	1.65	12.65	.50	4.35	.25	72.38
1963	33.80	8.70	12.42	----------	11.60	.50	2.95	.25	70.62
1964	35.22	9.30	11.75	----------	11.98	.50	2.95	.25	71.95
1965	32.68	9.20	15.03	----------	13.32	.50	2.95	.25	73.93
1966	27.45	9.88	12.38	----------	14.08	.50	4.35	.25	68.89
1967	20.36	6.43	12.20	----------	14.22	.50	2.95	.25	56.91
1968	20.36	6.43	12.37	----------	14.22	.50	2.95	.25	57.08
1969	20.36	6.43	12.35	----------	14.22	.50	2.95	.25	57.06
Total	[3] 278.24	[3] 78.04	[3] [5] 123.16	10.90	[3] [5] 121.04	5.00	[4] 32.43	2.60	651.41

[1] Not including special funds for basic research projects involving extensive international cooperation such as the proposed year-long international expedition to the Indian Ocean (estimated cost: $2 million).
[2] Not including military Research and Development operations.
[3] Less payments by AEC totaling $11.70 million for ship time.
[4] Plus $11.70 million for ship time, averaging $1.17 million per year.
[5] Includes recommended expenditures by the International Cooperation Administration and the State Department, for projects involving international cooperation and technical assistance to other countries.

Dr. REVELLE. Second, I thought it would be well to have both the Pacific Ocean, which, as you know, is the real ocean covering about half the world, and the small canal called the Atlantic Ocean represented here, I brought along a personal prop in the form of the Director of the Woods Hole Oceanographic Institution, Dr. Paul Fye.

Mr. THOMAS. We are glad to have you.

Dr. REVELLE. This is one of the nuggets that was spoken of.

Mr. THOMAS. How deep did you get this one?

Mr. YATES. What is it?

Dr. REVELLE. I will get to it.

Mr. YATES. It sounds like a mystery story.

OCEAN CURRENTS—ATLANTIC

Dr. REVELLE. I thought I would first talk briefly about a few of the outstanding results of the IGY program in oceanography. Perhaps the most interesting and far reaching was the work done on the currents below the surface of the sea. Ever since the days of Benjamin Franklin and, in fact, long before that, people have been aware of the fact that the surface waters of the ocean move in great currents as, for example, the Gulf Stream. Any globe or any map of the earth usually has a picture of these surface currents.

However, it is only within the last few years that it has been possible for us to determine that the ocean waters below the surface are also moving and we have just very recently developed methods of measurements and methods of analysis that will enable us to understand movements of the waters below the surface.

A typical thing about the oceanographic work of the past has been that it has been exploration. People have gone out and made measurements and recorded them and described what they measured or what they observed. It has not been possible in this science of oceanography until quite recently to use a standard method of science, namely, to have a hypothesis first, to have some theory that you want to test or some question you want to ask, but it is now becoming possible. Dr. Henry Stommel of the Woods Hole Oceanographic Institution made a prediction about the currents in the western Atlantic Ocean; namely, that underneath the Gulf Stream there would be found a current flowing in the opposite direction, from north to south, of rather high velocity, a velocity of about a half a mile an hour, and of very large magnitude.

At the beginning of the IGY the ships of the Woods Hole Oceanographic Institution and of the British National Institution of Oceanography made some measurements to test this hypothesis of Stommel's to ask the question of the ocean to see if they could get an answer and, lo and behold, the current existed. There is a current flowing underneath the Gulf Stream from north to south in just exactly the opposite direction.

DISPOSAL OF RADIOACTIVE WASTE

Mr. THOMAS. If you will yield, Doctor, when the Atomic Energy Legislative Committee meets on the subject of disposal, we certainly must have you there. Doubtless you have done a little thinking. With these crosscurrents, one at one level in one direction and one at another level going in the opposite direction, would it be wise to have a lot of study made before great quantities of harmful and poisonous atomic waste material are dumped in the ocean?

Dr. REVELLE. It certainly is highly desirable to make more careful surveys and careful analyses of the measurements before we dispose of very large quantities of radioactive wastes.

This has been considered by several committees of the National Academy of Sciences and by the Atomic Energy Commission. I think we can say at the present time two things.

One of them is that low-level waste can be disposed of fairly near shore in quantities of the order of a few hundred curies per month, let us say, in certain areas, not everywhere, but in carefully selected areas. The quantities may be increased, as has happened for Windscale, in the Irish Sea, to perhaps as much as 10,000 curies a month of low-level waste.

The second thing we can say is that it is quite certain that in the deep ocean we could dispose at the present time of quantities of the order of a few million curies without doing serious harm to any of the other resources of the sea. Whether we could dispose of the very large quantities of atomic waste that will be produced in the future of the order of thousands of millions of curies is not by any means clear at the present time.

Mr. THOMAS. It is a wonderful and sensible statement. It looks to me that perhaps the answer to the whole problem is further research in the subject of disposition of those materials. I think science will come up with the answer in 3, 5, 6, 7, 8 or 10 years, where the disposal of that product will be comparable to taking a pig to the slaughter-

house. They will not even lose the squeal. You will use all of that material and perhaps if you were to throw it away now, you would be throwing away a wagonload of money. Excuse me for interrupting.

Dr. REVELLE. This is something I should add. No nation at the present time has plans for disposal of high-level waste in the ocean. The engineers are thinking about storing it, continuing to store it on land or disposing of it in, for example, deep salt deposits on land.

Dr. BRONK. The committee might be interested in the findings of that previous committee of yours on the concentration of radioactive elements by marine plants and animals.

Dr. REVELLE. This is a real problem, that marine plants and animals tend to concentrate radioactive materials by factors of 10 to 100,000 over the concentration in the water. This is what makes it difficult to make predictions about how much can be disposed of.

Mr. THOMAS. Go ahead, sir.

PACIFIC CURRENTS

Dr. REVELLE. I was talking about the fact that it was actually possible to test a hypothesis. This is very rare in these earth sciences.

Another example of the discoveries on the subsurface circulation made during the IGY is the work done in the equatorial region of the Pacific by United States, Japanese, and the Columbian ships. Here the charts show very definitely a fast-moving current right at the Equator going to the west, moving at a speed of about 2 knots or about 2½ miles an hour, a very broad stream of water. Oceanographers in that region a few years ago lowered some fishlines into the water, down to depths of several hundred feet, and instead of moving to the west, as they thought they ought to, judging by what was on all the charts, they moved to the east. They said, there must be something wrong with our navigation. This just cannot happen. Everybody says the water here is moving to the west.

However, it was felt desirable to look into this further. During the IGY a half dozen ships spent about 2 months right along the Equator, and it was found again that there is a subsurface current moving in the opposite direction. This is a great river of water actually shaped like a ribbon, some 250 miles wide and about a thousand feet thick. Its top is about 200 feet below the surface of the sea and its bottom is about a thousand or 1,200 feet below the surface of the sea.

This enormous mass of water is moving to the east at a speed of about 2½ knots. It is a great ribbon or river in the sea moving toward the east. Underneath it is a third current moving toward the west, a very much thicker current, very much deeper but more slow moving, moving at only about a half mile an hour.

Mr. THOMAS. What about the width?

Dr. REVELLE. We do not know about the width of the deep one. We know the width of the middle one. The high-speed one moving toward the east is about 250 miles wide and about a thousand feet thick.

Mr. YATES. Did you not trace that to a group of islands?

Dr. REVELLE. This is just in the Pacific. We traced it 3,500 miles from an area south of Hawaii east to the Galápagos Islands. There is a curious thing about this current. It is not certain whether it

exists east of the Galápagos Islands. It seems to come up to the Galápagos Islands and stop. What in the world happens to the water? Does it go into a big hole in the ground? It seems unlikely. The water must turn to the north or turn to the south or something, but we have no idea at the present time what happens to it. This is one of the things we are dying to go down and have a look at.

Mr. YATES. Can you go down that deep?

Dr. REVELLE. I was thinking of going down to the Equator and lowering measuring instruments. This great current has a great transport of water, a river a thousand times the volume of the Mississippi River.

Another example was a study of the equatorial countercurrent to the north of the Equator, which had always been thought to be a very shallow current, and it turned out to be at least 3,000 feet thick and to carry about three times as much water as everybody had thought previously, about 2,000 Mississippi Rivers. It is a huge current, very much bigger than had previously been thought.

Our whole concept of the general circulation of the ocean, where the water comes from and where it goes and how these currents are connected, has now been thoroughly upset.

In this field of the IGY at least, as so often happens in science, we know more now than we did before, but we know the problems facing us are much greater and more complicated than the problems we started with.

HEAT FLOW THROUGH THE CRUST

Another development of the same kind was the study of the heat flowing from the interior of the earth through the sea floor. Some measurements have been made prior to the International Geophysical Year. These measurements suggested that we would find a pattern on the sea floor, that underneath ridges such as, for example, the mid-Atlantic ridge, which is the spine of the Atlantic Ocean, and the great Albatross Plateau, which extends from Antarctica north to Mexico in the Pacific, we would find a lot of heat coming from the interior of the earth, whereas, along the South American coast and great gashes or trenches that parallel the coast and lie quite close to it, we would find a very small amount of heat coming from the interior of the earth.

During our Downwind expedition during the first part of the IGY, a great many measurements were made of the heat coming from the interior and indeed this proved to be the case. The heat flow coming from the earth underneath the ridge was about seven or eight times the average value, so high that if your previous ideas about how it got out were correct, namely, that if it were simply conducted out like heat is conducted along a rod—that the rock would be molten at a depth of a few miles. Actually we know from seismology that the rock is not molten. Something very funny is happening here to give this enormous quantity of heat in this area.

On the other hand, west of that area, between the two and the Equator, the heat is very low. There is a real pattern to this heat flow from the interior which strongly suggests that in fact the inside of the earth is like porridge that is being heated and slowly turning over and carrying heat by what is called convection.

OCEAN BOTTOM DEPOSITS

The third interesting discovery was the discovery of the extent of these materials here.

This [indicating] is a crust of manganese dioxide and this is what is called a nodule of manganese dioxide. Each of these contain about 25 percent manganese and somewhere between a half and 1 percent of nickel, a half and 1 percent of cobalt, and about 1 percent of copper.

Mr. YATES. Where do you find them?

Dr. REVELLE. These occur over very large areas of the sea floor and the IGY theory is that the abundance of this material and its extent—I can give you some figures on this—the metals in this material are worth about $45 a ton. There are somewhere between 15,000 tons per square mile and 120 tons per square mile over millions of square miles in the Pacific.

We also believe that they exist over very large areas of the Atlantic.

Dr. BRONK. How much does it cost to get them up?

Dr. REVELLE. The depths range from 1,500 feet to fifteen to twenty thousand feet.

Mr. YATES. You can offer competition to Arizona one of these days?

Mr. RHODES. That is what I am afraid of.

Dr. REVELLE. The Mineral Technology Division of Berkeley has looked into the possibility of mining this material and recovering it. Their report is quite optimistic, but my own opinion is that it is way too optimistic. Nevertheless, it does seem that something should be further investigated. For example, it might be very well that you could actually extract the metals in this material, transport them to where you want them, recover the material, and extract the metals and transport the material for somewhere around $30 a ton, giving about a $15 a ton profit.

This may be way overly optimistic as a figure, but nevertheless it should be thoroughly investigated.

U.S.S.R. OCEANOGRAPHY

One other result of the IGY has been that we have been able to get a better appraisal of Russian oceanography. For example, when the Russian ship *Vityaz* was in San Francisco a few weeks ago, a lot of people went up to look at it, and I think that our present feeling about Russian oceanography is that it is a very effective survey operation on a very large scale and growing larger all the time whereas American oceanography has tended to go beyond the survey type of thing toward asking and attempting to answer questions about the ocean.

Mr. YATES. If I understand you correctly, it is more like our Coast and Geodetic Service?

Mr. REVELLE. No; I do not mean that. Scientific oceanography and the study of temperature and currents and so forth, the Russians are doing in a sort of systematic routine, in what strikes one as a fairly unimaginative way or on a fairly unimaginative basis.

Mr. RHODES. Would you yield at that point?

Is there any great amount of benefit to be derived from all of that information in as massive a quantity as they are apparently trying to get it?

Dr. REVELLE. I think there is a very great need for knowing it from a variety of points of view.

Mr. RHODES. I mean, a superficial knowledge like the Russians seem to be getting by their survey methods?

Dr. REVELLE. I think that is an essential requirement in understanding the ocean, to have more adequate surveys. I will come to that in just a minute.

FUTURE PROGRAMS

As for the future, I would like to mention three things: First, planning for international cooperation; second, the future oceanographic program of the United States; third, possibilities of studying the earth itself underneath the ocean.

SCOR

As one result of the IGY, the International Council of Scientific Unions has organized a Special Committee on Oceanographic Research which represents many different countries, just as the Special Committee for the IGY did. They are laying plans for a variety of cooperative ventures, particularly an international expedition to the Indian Ocean, which would involve some 16 ships and would last for about a year. This is the largest unknown area on earth. It is one of considerable interest, both because of the rich potential fishery resources and because of the fact that the changing monsoon winds change the circulation pattern and we would like to know how the atmosphere and the ocean are linked together here.

A very large area of the sea floor is so little known.

Another program of this international committee is to continue to try to obtain a good assay of the amount of carbon dioxide in the air which is increasing because of the burning of oil, coal, and natural gas, and which is decreasing because of absorption by the ocean.

UNESCO and the International Cooperation Administration of the United States are also concerned with international cooperation in oceanography, particularly in attempting to give technical assistance to underdeveloped countries and to improve their use of marine resources and fishery resources. They are both absolutely essential for the survival of those people because it is their principal source of protein.

NAS COMMITTEE ON OCEANOGRAPHY

As far as the United States own program is concerned, this has been spelled out in great detail by a committee of the National Academy, a Committee on Oceanography headed by Harrison Brown, of Cal Tech.

In the material I have submitted for the record, I have summarized the report of that Committee.

Briefly, the Committee recommends that some 70 new oceanographic ships should be built by the United States during the next 10 years—70 ocean research and survey vessels. This would increase our ocean research and survey fleet by about 45 ships because our present ships are for the most part obsolescent or out of date.

Secondly, the committee has recommended that there should be an intensive national and international program of oceanwide surveys.

The Coast and Geodetic Survey and the Hydrographic Office, which are our principal American survey agencies, have concentrated almost entirely on surveys of the Continental Shelf near the areas of land. We believe and feel quite strongly that there should be surveys of an accurate and comprehensive nature made of the currents, water, biology, and the bottom, as well as magnetism and the gravity topography of the bottom on a worldwide basis. This should be done by international agreement in which the United States would take perhaps 30 percent of the world's ocean as its share and the remaining maritime powers would take the other 70 percent.

We have recommended that an intergovernmental conference should be called to arrange such a survey program and that a world oceanographic organization should be established, like the World Meteorological Organization, to accumulate and foster the use of data obtained by the surveys.

As far as the special interest of this committee is concerned, the National Science Foundation has recommended a total of some $650 million should be spent by the Federal Government during the next 10 years in oceanography; about $123 million should be spent by the NSF. They should support about half of all the basic research in that field. They should spend about $10 million for oceanographic research vessels and about $12 million for research operations over the next 10 years; some $5 million for new items such as bathyscaphes for exploring the ocean and about $45 million for research facilities and in research operations.

Our recommendation, of course, is quite apart from what may actually happen.

The average expenditure by the NSF for marine sciences should be about $12 million a year for the next 10 years.

DEEP DRILL THROUGH THE CRUST

Finally, I would like to point out that one very exciting program for studying the earth is now being considered by the National Science Foundation and the National Academy. That is the program for drilling into the deep sea floor to a depth right through the crust of the earth down to the mantle of the earth. We talk glibly and learnedly about what the earth is made of and how it is put together but nobody has any idea whether we are right or not. We will not have an idea until we drill down into the earth to find out what is there. This is the only real way to do that.

Mr. THOMAS. You mean you are going to drill to the bottom of the ocean, Doctor?

Dr. REVELLE. That is what we propose to do. Oil companies are doing that now and they are capable of drilling now through water some 1,500 to 3,000 feet deep.

Mr. THOMAS. You want to drill in water that is 10,000 feet deep?

Dr. REVELLE. We would like to drill through water that is about 15,000 and then through rock for another 15,000 feet.

Mr. YATES. Is it not easier to do it on land?

Dr. REVELLE. No; because on land you get down to the mantle of Old Man Earth, the interior, and you have to go down to at least 100,000 feet or probably 130,000 or 140,000 feet. This is beyond present drilling capabilities.

Mr. THOMAS. Suppose you hit an oil well down there? What would you do if you were drilling in 15,000 feet of water and hit an oil well?

Dr. REVELLE. These oil company people drilling in water do not think that is much of a problem.

Mr. THOMAS. That is, not in the couple of companies where they are drilling 15,000 feet.

Go ahead, Doctor.

MONITORING OF SUBMERGED VESSELS

Dr. REVELLE. That is all I have to say except that I would like to mention one other thing, and that is that this National Academy Committee on Oceanography has felt, or feels, that even more of a problem than inspection of nuclear explosions will ultimately be, if we are going to have a peaceful world, our ability to monitor submerged vessels in the ocean—in other words, submarines. We must make the ocean transparent and we must have a really adequate monitoring system for all submerged submarines, everywhere in the ocean and at all times, if we are going to eliminate what seems to us to be the most serious threat to peace that we now have or perhaps the most serious.

Mr. THOMAS. Is that the job for you oceanographers, or people dealing with sonar?

Dr. REVELLE. These things involve two things. We cannot deal with sonar unless we understand the ocean and you cannot deal with the ocean unless you deal with sonar and other devices for getting information through sea water. You cannot see through the water. You have to hear through it or use other ways.

Mr. THOMAS. In developing one, you have to develop the other?

Dr. REVELLE. That is right.

Mr. YATES. Is sonar your exclusive method of detection at the present time?

Dr. REVELLE. No; there are other methods.

Mr. YATES. Are they classified?

Dr. REVELLE. Yes; we do not want to go into that.

Mr. THOMAS. That is a wonderful statement and that is exactly what we expected from you; nothing short of it. You always deliver.

Mr. JONAS. May I ask a question?

Mr. THOMAS. Yes.

SCIENTIFC USE OF SUBMARINES

Mr. JONAS. Did we get any useful information from it other than the knowledge that they negotiated that distance under the arctic icepack with submarines? Did they pick up any useful information on those trips?

Dr. REVELLE. Yes; I think they did. There were two scientists on those ships; Dr. Waldo Lynn, on the *Nautilus*, and Eugene LaFonte, on the *Skate*. They got quite a bit of sounding information and some information about the water.

Mr. JONAS. New information that we had not known?

Dr. REVELLE. That is correct.

Mr. JONAS. Or suspected?

Dr. REVELLE. You cannot suspect. You cannot really suspect what the shape of the bottom is like. We did get good soundings across the Arctic. Oceanographers in general are quite enthusiastic about the submarine as a tool.

Mr. JONAS. That was the next question I wanted to ask you. You envision a large field of surface ships in the next 10 years?

I wondered if much of that work could not better be performed or accomplished with submarines?

Dr. REVELLE. I think it is fair to say this: We definitely need to use undersea vessels, but these undersea vessels should be of a type quite different from the present submarine. They should be capable of going down to the greatest depths of the sea and moving around at any depth. They should be vessels that have as accessories the bathyscaphe or the present underwater balloons where people go down to about 15,000 feet. They should actually be flying-through-the-water things like an airplane flies through the air and control their depth by the height of——

Mr. JONAS. Actually, most of your exploration will have to be underwater anyway. If you are doing it from a surface ship, you have to send men down underwater.

Dr. REVELLE. Actually, you need both. A great deal can be done with instruments. An oceanographic surface ship is merely a platform for carrying winches around which are lowered into the water. Any contraption which you use to send men down from the surface usually requires a surface ship to act as a tender. The instruments that we will use with men are simply instruments that are another kind of instrument that you lower from an oceanographic ship.

Mr. RHODES. This undersea boat that you are talking about, would it carry its own proplusion system?

Dr. REVELLE. Yes, sir.

Mr. RHODES. Would it be capable of sustaining itself out in the middle of the ocean without a tender?

Dr. REVELLE. No.

Mr. RHODES. It would be based on a surface tender?

Dr. REVELLE. Yes; but not at the present time.

Mr. RHODES. What about the engineering? Could we explore the bottom of the ocean in the deepest parts with a boat like the one you mentioned?

Dr. REVELLE. We are quite certain that this can be done because, as I say, bathyscaphes and underwater balloons now exist and go down to 15,000 feet. The problem of carrying them down to 35,000 is well within our physical capabilities. One of the important recommendations of the Committee was that we should really get industry involved in this business of undersea exploration on a much larger scale than it has been done in the past. Oceanography has been a rather primitive, poorly supported, thrifty kind of science. If we are going to do as well, for example, as the space merchants, whom you are going to hear from in a minute, we have to do that.

Mr. THOMAS. Let us come back at 10 minutes to 1.

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AFTERNOON SESSION

Mr. THOMAS. Gentlemen, will the committeee please come to order? When we recessed for luncheon, I think our distinguished friend and guest, Dr. Revelle was talking.

Doctor, will you proceed?

Dr. REVELLE. I am all through, sir.

Mr. THOMAS. During the luncheon hour, I heard a lot of nice things about all of our friends here this morning.

Dr. Kaplan, who is next?

Dr. KAPLAN. Dr. Wexler, Mr. Thomas, who will combine both his report and that of Dr. Gould.

Dr. Wexler's report is on meteorological and glaciological programs, and Dr. Gould's on Antarctica.

Mr. THOMAS. Dr. Wexler, we are honored to have you with us. Of course, you are part of the Committee too. The doctor is one of the old timers and a real valuable servant of the country. He has been with the Weather Bureau for many, many years and is one of the top scientists of the country. Doctor, we are delighted to have you. We want you to talk for yourself and for our friend Dr. Gould, too.

Dr. WEXLER. Thank you, Mr. Thomas.

STATEMENT OF DR. L. M. GOULD CONCERNING ANTARCTIC PROGRAM

Mr. THOMAS. We will insert Dr. Gould's prepared statement at this point.

(Dr. Gould's statement follows:)

I. IGY ANTARCTIC PROGRAM

I am pleased to appear before this committee again to tell you something of the results of the IGY programs in the Antarctic. I shall also take this opportunity to tell you of some of the steps, both national and international, which have occurred to continue scientific research in the polar areas. I plan to cover broadly the scientific achievements in the Antarctic programs, Dr. Wexler and other witnesses having already given a more detailed account of the scientific results of IGY Antarctic research.

The extensive geophysical scientific investigations which have been made in this region have been most fruitful and the achievements of our scientists in these remote regions are indeed something of which all U.S. citizens may be justifiably proud. Particularly with regard to the Antarctic I should like to bring to you the conception of the scientific opening up of a continent—for the first time in history we have garnered a body of scientific data in all geophysical fields which will permit us, albeit in a preliminary way, to understand this vast area of ice and snow, with the world's coldest climate, which holds the key to so many geophysical enigmas.

Before commencing my report on the scientific programs I should like again to acknowledge the tremendous accomplishments of Department of Defense agencies in rendering logistic support to our scientists in this most remote and isolated region and under the most difficult possible circumstances. As you know, Navy Task Force 43, assisted by the Air Force, provided the logistic support for the IGY program in the Antarctic, while the Army also contributed in many ways including, notably, the blazing of the original trail from Little America to the Byrd Station. The leadership of Rear Admiral Dufek in establishing and maintaining our six IGY stations has been a tremendous feat of marshalling men, materials, and facilities and without his untiring enthusiasm and perseverance we could not possibly have achieved the successes we can claim. As you know, the Admiral is retiring with the close of this season's operations and I, who have been so close to this phase of our U.S. IGY program, should like to take this opportunity to pay the tribute which he so richly has earned.

ANTARCTIC SCIENTIFIC PROGRAM

In the brief time available to me I cannot begin to tell you of all of the scientific findings which are evolving from our program in Antarctica. I am compelled to deal in generalities for there is so much to say; and other scientists here can tell you better than I the details and significance of the scientific discoveries in their particular fields of interest.

Also, I shall not again take the time to review the tremendous effort of the United States, in establishing and maintaining the six IGY stations on this frozen continent—the earth's last empty quarter which has never been the home of man. We have reviewed these tremendous accomplishments with you before, and it is an achievement in which all Americans can take great pride.

However, it may interest you to know that a total of approximately 27 tons of scientific data in the fields of aurora, geomagnetism, ionospheric physics, meteorology, seismology, geology, glaciology, cosmic rays, and biology have been collected during the IGY antarctic program. All of these data, ranging from mummified seals hundreds of years old to digital computer punchcards, have been safely loaded on board ships and are now en route to the United States where they will be transported as quickly as possible to various research institutions for study, analysis, and reduction, and thence to the 11 U.S. IGY data centers. Of this total, approximately 10 tons of data were received from the Antarctic during the first year of the program. When these data are fully studied and coordinated with the scientific information arriving in our data center from the 40-odd antarctic stations of 11 other nations, we shall truly begin to understand this great continent. Thus, again, much of the scientific significance of our work in the Antarctic will only evolve during the next few years as these data are screened and analyzed and correlated with data taken at all of the IGY stations in Antactica nd, indeed, throughout the world.

However, let me here tell you some of the most immediate discoveries, the high spots of our findings up to now which I know will interest you.

You will recall some of the more outstanding findings of the first traverses on which we reported to you last year: the discovery of new mountains and botanical life at 82 degrees south by the Ellsworth traverse; the tremendous depth of ice cover (up to 14,000 feet) in the region close to the Byrd station; and the existence of a deep trough extending from the vicinity of the Ellsworth station toward the Ross Sea, implying a possible division of east and west Antarctica.

Professionally, as a geologist, I must single out one exciting discovery of the Byrd station traverse during the past summer season for particular mention. Dr. Charles Bentley and his team journeyed south from Byrd until they reached the northern edges of the Horlick Mountains. There, to their amazement and delight they found a tremendous store of fossils: a petrified tree approximately 12 feet long, leaf fossils, fossil bivalve shells and coal beds varying in thickness from a few inches to 30 to 40 inches.

While this particular discovery is most exciting to me personally, I must pass on. Let me turn to some of our other discoveries, always bearing in mind my earlier caution that we shall not know the true value of this program until the vast amount of data we have secured has been analyzed and correlated here at home. In order to save time, I shall briefly enumerate several of the more interesting findings.

Evidence continues to mount that a great trough may extend from the Ross Sea area toward the Weddell Sea. Last year we reported the discoveries of the Ellsworth traverse that a trough extended inland in the direction of the Byrd station, and the confirmatory evidence that the region about 100 miles from Byrd station rests on rock 8,200 feet below sea level with an ice cover 14,000 feet thick. Further confirmation of this trough is now reported by the seismic measurement of a trough trending inland from the Ross Sea. Thus, west and east Antarctica may actually be separated by a major geological division.

Ice measurements in Antarctica, where 90 percent of the world's ice is estimated to be, requires upward revision of the world's total by at least 40 percent, to nearly 6,500,000 cubic miles. This finding bears importantly on the studies of the delicate balance of the earth's heat and water budget. These statistics should not be interpreted to mean that the great Antarctic icecap is growing. On the contrary, all available evidence shows that the icecap was formerly much thicker and more extensive than now. Glaciated mountaintops a thousand feet above the present ice levels have been found at various places. Further indication of the thinning ice and the resultant rising of the land underneath due

to the decreased load is the presence of raised beaches in the McMurdo Sound and some other coastal areas.

A record low temperature of —125.3° was reported by Soviet scientists at an IGY station near the center of the Antarctic Continent. At the South Pole itself, where a temperature of —102.7° has been recorded, radiation studies have shown that during the Antarctic midsummer the pole receives more sunlight than any place else on earth. At the same time, radiation studies at Little America have also demonstrated the striking clarity of the Antarctic atmosphere where solar radiation at sea level has been found to equal that at 3,000 to 6,000 feet in the European Alps. Similarly, the ozone content of the air in Antarctica has been discovered to have values as much as 30 percent more than that found in parts of the United States, a surprising fact which leads to speculation that air must be infiltrating over the continent from lower latitudes, since ozone is manufactured naturally only in the sunlit portion of the lower atmosphere.

Seismographs installed at several U.S. stations have recorded surprising earthquake activity, over 3,000 quakes having been recorded at the South Pole alone during the past year. As Antarctica had heretofore been a blank spot in the global net for earthquake recordings, the IGY program in this field promises to provide a major addition to our understanding of global seismographic activity. The seismograph at Wilkes station has been found to have special importance since this station is diametrically opposite the southern tip of South America. Thus, earthquakes from the latter region travel directly across Antarctica where they are recorded at Wilkes. Recent analysis of the group velocities of these earthquake waves has just provided further basic information on the question of whether Antarctica is continental in character or an island group.

Deep drilling operations, which at Byrd station have bored more than 1,000 feet into the ice, have brought up cores which fell as snow more than 1,000 years ago. Reading the layers of deposits in these cores, much as one reads tree rings, will tell us much of past climatic changes.

In the auroral program the startling discovery was made last August of a new twilight phenomenon, the presence of a line at wavelength approximately 6,700 angstroms. First reported at the joint New Zealand-United States Hallett Station, and by the New Zealand station at Invercargill, New Zealand, it was afterward recorded at several U.S. antarctic stations. This radiation has been attributed to lithium in the high atmosphere and plainly suggests an inference that it may have been related to nuclear tests carried out during this period.

I cannot begin to touch upon the significance of the vast importance of 2 years of meteorological data taken throughout the continent, and others who are here are far more able than I to discuss the importance of these records. However, let me say, as has been said before, that these coordinated observations have for the first time enabled us to draw daily weather maps of the world's greatest cold weather factory and to begin to understand its influence on the more temperate regions. Here I must pause to note the unique program of the international weather central at Little America. This was truly an international undertaking for, in addition to U.S. scientists, meteorologists from Australia, Argentina, France and the U.S.S.R. have wintered there, and New Zealand and South African scientists took part in the programs during the summer season. All stations in the antarctic contributed daily weather information to the center which, in turn, prepared analyses and forecasts of the weather patterns in Antarctica four times a day. I am particularly pleased to learn that this center will be continued by Australia after the IGY for I predict that this information will become increasingly important and practically necessary with man's increased global travel and the coming of our jet age.

Weather records at Little America, intermittent for the last 50 years but, of course, continuous during the IGY, have shown a 5° warming of the climate at that location during this period. While this interval is brief according to the geophysical time scale, at least we have a significant and short-term trend. I know that the inherent possibilities of this trend have been pointed out to you before, but I cannot refrain from noting again the significance of melting of only a few feet of ice to our coastal climates and civilization; great changes have occurred in Antarctica in the past as the fossil deposits to which I have referred indicate, and they could recur again.

In the ionosphere of the Antarctic, subject as it is to continuous solar ionizing radiation during the summer on the one hand, and completely screened from the sun during the long winter night on the other, new discoveries have also been made. Particularly we must revise our thinking of the nighttime ionization mechanisms, for it has been found that the F-layer persists probably, however,

breaking up into cloud formations. This suggests that electronic clouds may drift from the winter sunlit regions of the ionosphere toward this polar region—or we must postulate some new mechanism to explain the persistence of this ionization throughout the winter.

While this review has been all too brief, my time is limited; I hope, however, that my remarks will indicate to you the scope of our scientific achievements in the Antarctic during the IGY and will hint at the tremendous promise in the data which is now being brought back.

II. POST-IGY POLAR PROGRAMS

I should now like to take a few moments to tell you about the developing plans for continued research in the polar regions after the International Geophysical Year, for I firmly believe that the beginning we have made during this interval will only be capitalized upon if we can continue our work in these remote regions. In so doing, I should like to discuss plans for both the Antarctic and the Arctic, for if we have learned one thing from the IGY, it is that geophysical phenomena in both of these regions are inextricably associated. It is for this reason that the Academy has established a committee on polar research, about which I shall have more to say a bit later, whose responsibilities embrace both the Arctic and the Antarctic.

A. The Antarctic Program

I shall speak first about the Antarctic. I am sure that our many presentations to you in the past have emphasized the necessity for planning for scientific research in the Antarctic long in advance of the time when our scientists and their equipment and supplies must begin the journey to their isolated stations. For this reason the U.S. National Committee for the IGY and its Antarctic Committee began as early as the summer of 1957 to give consideration to the problems associated with continued research in the Antarctic after the IGY. While we recognized that our formal obligations would be concluded with the termination of the IGY program, as scientists we were seriously concerned that the advantages gained from the established facilities and from the vast store of scientific knowledge acquired during the IGY should not be lost, but should be fully capitalized upon by a continuing program of research.

Accordingly, recommendations that planning be initiated for a post-IGY program of research by the United States in the Antarctic were first transmitted to the president of the National Academy of Sciences and the National Science Foundation during this period.

Meanwhile, within the international community of scientists similar planning for continued cooperative research in the Antarctic was being stimulated. The matter was first formally considered at an ad hoc Antarctic meeting in Stockholm on September 9–11, 1957, at which delegates from the nations having IGY programs in the Antarctic were convened to begin the planning for post-IGY Antarctic research. This meeting examined at length the need for and scientific opportunities to be gained by continued international cooperation in Antarctic research and concluded "that there is much to be gained from continued observations in Antarctica, and that there are some nations which seem to be able and willing to take up this task." The meeting also recognized major advantages in using the International Council of Scientific Unions (ICSU) to promote cooperation between ICSU-adhering national scientific bodies as well as the additional advantages in utilization of the ICSU and to provide for the collaboration of ICSU scientific unions in the formulation of the research programs.

These activities, both national and international, culminated in the establishment by ICSU of a Special Committee on Antarctic Research (SCAR) in October 1957 and by the U.S. National Academy of Sciences of a Committee on Polar Research in February 1958.

SPECIAL COMMITTEE ON ANTARCTIC RESEARCH (SCAR)

The SCAR held its first meeting at The Hauge on February 3–5, 1958, and a second meeting in Moscow on August 4 and 11, 1958. The third meeting is now scheduled for Canberra, Australia, on March 2–6, 1959. The scientific academies of countries having established IGY Antarctic programs were invited to membership in the SCAR: Argentina, Australia, Belgium, Chile, Great Britain, France,

Japan, New Zealand, Norway, South Africa, the United States, and the U.S.S.R. In addition, the ICSU International Unions on Geodesy and Geophysics, Scientific Radio, Biological Sciences, and Geography have membership in the SCAR.

Dr. Harry Wexler and I were pleased to receive appointment as the Academy's delegates to the SCAR.

First meeting of SCAR

The first meeting of SCAR was largely organizational in character. A constitution, specifying the objectives of SCAR with "furthering the coordination of scientific actiivty in Antarctica, with a view to framing a scientific program of circumpolar scope and significance," was developed and three scientific working groups were established to define the objectives of the research programs for the years following the completion of the IGY program.

General recommendations were prepared by these working groups as guidance to the national delegates in developing their respective programs. These recommendations took particular note of the IGY programs and recommended their continuation in order further to profit from the significant achievements of the IGY. However, the need for additional stations, five in the interior at strategic locations and seven at the following coastal locations were specifically cited:

(i) A station between Hallett and Durmont d'Urville.
(ii) A station between Durmont d'Urville and Wilkes.
(iii) A station east of the Weddell Sea.
(iv) A station southwest of the Weddell Sea.
(v) Three stations betwen the Palmer Peninsula and the Ross Sea.

I should like particularly to call to your attention the recommendations of this first SCAR meeting for broadening the scientific programs in Antarctica. For the first time recommendations were adopted that all countries plan together and initiate comprehensive new scientific programs in biology and physiology, in geology and geomorphology and in a coordinated program of cartographic mapping of the continent for scientific purposes; programs in vulcanology were also recommended, as well as an expanded program in seismology to insure adequate coverage of the region. Programs of rocket soundings were adopted as most important to meteorology and to high atmospheric physics. Finally, the need for substantially larger programs of Antarctic oceanography was stressed, it being recognized that a substantial portion of the IGY program in this field had had to be conducted from expeditionary vessels whose first objectives was support of the IGY Antarctic stations.

Opportunity was given to all delegates to present their scientific plans for continuing programs of research. Although several representatives, including Dr. Wexler and myself, were unable at that time to present definite programs for the first post-IGY Antarctic program, it was most notable that all delegates were enthusiastic over the prospect of continued international collaboration in this region.

Second meeting of SCAR

The second meeting of the SCAR convened in Moscow in early August of last year. I regard the most significant fact of this meeting as being the enthusiastic and concrete announcement by all countries that they would indeed continue their IGY scientific programs in the Antarctic, and that many had firm plans for expanding their research work into the new scientific fields recommended at The Hague. National reports were given by all nations outlining these plans, and I am happy to report that, with one or two exceptions, all stations occupied during the IGY will continue with full scientific programs.

Of particular interest to you may be the addition of a Polish station at Bunger Oasis formerly occupied by the U.S.S.R. We have recently received word that Poland will make observations in meteorology, geomagnetism, seismology, gravity, and nuclear radiation during the present season; the following year I am told, they will expand this program to include also research in ionospheric physics, auroral physics, geology, and glaciology.

I should also mention that the U.S.S.R. announced its intention to establish additional stations, following the recommendations of the first SCAR meeting. In particular, they now have expeditions en route to a new location on the Queen Maud Land coast and hope also to be able to establish a station on the Bellingshausen Sea, west of the Palmer Peninsula.

Time will not permit me to go fully into all of the plans and programs developed at the second meeting of SCAR, but the following particular points should be noted:

(i) A firm program for gathering and distributing cartographic information was established. Plans were initiated for the development of an accurate map of Antarctica and each country was encouraged to develop detailed plans for new mapping programs.

(ii) The tremendous value of international exchange of scientists at antarctic stations during the IGY was noted and strong encouragement to continue such activities in post-IGY programs was extended.

(iii) A detailed program for enlarged research in physical oceanography and marine biology was adopted.

(iv) Expanded programs of gravity, glaciology, geomagnetism, aurora, and ionospheric physics were defined and approved for future implementation.

(v) Major redefinitions of the objectives in meteorology were developed, placing emphasis on the heat and moisture budget of the antarctic atmosphere, the broad scale processes and influence of antarctic meteorology on the remainder of the Southern Hemisphere, and on special observations for the investigation of atmospheric composition, albedo, micrometeorology, etc.

(vi) The need for rocket sounding programs was reaffirmed and emphasized as most important.

(vii) Continuation of the Antarctic Weather Central in Australia or New Zealand was recommended. (Australia has since accepted responsibility of this most important activity.)

(viii) Arrangements for continuation of the mother-daughter international radio communications network among all antarctic stations were discussed and initial steps taken to ensure its perpetuation.

NAS Committee on polar research

As I have already mentioned, these international developments and the recognition by the scientific community in this country that the United States must continue its programs of polar research after the IGY, led to the establishment of the Academy's Committee on Polar Research in February 1958. I was most pleased to be requested by Dr. Bronk to become chairman of this committee. Its membership, and that of the panels which assist in the formulation of program plans and recommendations, is as follows:

Committee on Polar Research

Dr. Laurence M. Gould, Chairman
Dr. René J. Dubos
Mr. Carl R. Eklund
Dr. Trevor Lloyd
Dr. P. F. Scholander
Mr. Alan H. Shapley
Dr. Robert P. Sharp
Dr. Athelstan F. Spilhaus
Dr. Merle A. Tuve
Dr. A. Lincoln Washburn
Dr. Harry Wexler
Mr. R. C. Peavey, Executive Secretary

Panel on Biological and Medical Sciences

Dr. William J. L. Sladen, Chairman
Lt. Col. Anthony Debons
Dr. René J. Dubos
Mr. Carl R. Eklund
Dr. Marshall B. Jones
Dr. Kaare Rodahl
Dr. P. F. Scholander
Dr. Lionel A. Walford
Dr. Neal A. Weber

Panel on Earth Crust and Core

Dr. George P. Woollard, Chairman
Dr. J. R. Balsley
Dr. Walter H. Bucher
Dr. R. P. Goldthwait
Dr. Harry H. Hess
Dr. Frank Press
Dr. Robert P. Sharp

Panel on Geodesy and Cartography

Mr. R. H. Lyddan, Chairman
Dr. W. A. Heiskanen
Mr. O. M. Miller
Mr. George D. Whitmore
Mr. Charles A. Whitten

Panel on Heat and Water

Dr. Bernhard Haurwitz, Chairman
Dr. Henri Bader
Dr. Franklin I. Badgley
Mr. William O. Field
Mr. Gordon G. Lill
Dr. John Lyman
Dr. Edward A. Martell
Mr. William G. Metcalf
Dr. Roger R. Revelle
Dr. Athelstan F. Spilhaus
Dr. W. S. Von Arx
Dr. Harry Wexler

Panel on Upper Atmosphere

Mr. Alan H. Shapley, Chairman
Dr. Herbert Friedman
Dr. C. W. Gartlein
Dr. C. T. Elvey
Mr. Norman J. Oliver, Jr.
Dr. H. E. Vestine
Dr. J. R. Winckler

At this point I should digress for a moment and ask you to note that this is a Polar Committee—whose scientific interests embrace both the Arctic and the Antarctic. While the time scale and the newly found importance of cooperative research in the Antarctic induced the ICSU to establish a committee for the Antarctic, our own national interests, both political and scientific, are also inextricably associated with the Arctic. Moreover, our expanded national activities since World War II in the Arctic, plus the added stimulus for research afforded by the IGY in this region, clearly indicated the urgency for more adequate scientific programs in this region. Accordingly, Dr. Bronk concluded that one committee should give consideration to the scientific interests and opportunities of the United States in both polar regions.

Attention of the Committee was first given to the development of program and budgetary recommendations for the scientific programs in the Antarctic in 1959. These programs were intentionally designed to capitalize upon the tremendous investment in the facilities, resources and experience which has been developed during the IGY antarctic program as well as to capitalize upon the scientific findings gained internationally throughout the Antarctic during the IGY program. In addition, the program was broadened, consonant with international plans agreed to at SCAR by the other nations, and now includes, for the first time, basic work in geology and the biological sciences, as well as a supporting program of antarctic mapping which is so necessary if we are to broaden our scientific horizon.

These recommendations were, in the customary fashion, made to the Government through the National Science Foundation which had received an Executive directive for the conduct of this Nation's scientific programs in the Antarctic for the post-IGY period. We were most grateful to the House Appropriations Committee for making arrangements to provide $2 million with which to undertake the 1959 antarctic program.

During the past year we have also made recommendations to the National Science Foundation for continuing programs in the Arctic following the close of the IGY program, and for 1960 in the Antarctic, since, as you know, leadtime in the development and implementation of these programs is most important.

To conclude my presentation I should like to review for you the 1959 antarctic program and the recommendations of the Committee on Polar Research for future polar programs.

Antarctic program, 1959

As you know, this program is now being conducted. While I refer to this as the 1959 antarctic program I should remind you that actually its expeditionary aspects extend from September of 1958, when the scientists and their equipment began to move into the stations, to February or March of 1960, when they are returned by the Navy task force vessels; a similar time scale will, of course, apply for the 1960 antarctic program and each of those which follow.

In brief, the U.S. program for 1959 includes—

(i) Two scientific stations, Byrd and pole stations, staffed fully by U.S. personnel;

(ii) Hallett station staffed jointly with New Zealand;

(iii) Certain special scientific programs which will be conducted at the Naval Air Facility, McMurdo Sound;

(iv) Wilkes and Ellsworth stations, where three and one U.S. scientists, respectively, will work cooperatively with Australian and Argentine scientists; and

(v) Three scientists cooperating at the New Zealand Scott base.

This program, however, represents a sharp reduction in our antarctic efforts as compared with the IGY period. In point of fact, we have cut back (leaving aside the small-scale cooperative effort at Hallett) from five major stations to two—the one at the South Pole and the one in Marie Byrd Land. Scientific traverses are also planned for conduct during the 1959–60 antarctic summer and oceanographic investigations are being conducted aboard expeditionary vessels.

Of particular interest, perhaps, in this program is the initiation of a program in the biological and medical sciences, for which a new laboratory has been installed at McMurdo Sound, and the beginnings of a program in geology which we hope can be substantially expanded in future years.

The current program is outlined, station by station, in more detail below.

Pole station.—A full program of research is continuing at the pole station, auroral, geomagnetic, ionospheric, and seismic observations are being made. The meteorology program of three hourly surface and twice daily upper air observations has been expanded by the addition of radiation, ozone, and CO_2 programs.

Byrd station.—The scientific program at Byrd station in 1959 is continuing research carried out at this station during the IGY. Observing programs include aurora, geomagnetism, glaciology, seismology, ionospheric soundings, radio noise recordings, and whistler recordings. The meteorology program is continuing standard surface and upper air observations, as well as special radiation measurements. During the summer of 1959–60, a traverse will operate from the station toward the north and northwest coast of Marie Byrd Land; glaciological observations, seismic soundings, and gravity and magnetic measurements will be made on this traverse.

Naval Air Facility, McMurdo Sound.—A biological laboratory has been provided for biological work in the McMurdo Sound area. During the 1958–59 summer a survey of respiratory infections and investigations of fungus disease in penguins and of the internal parasites of mammals and birds was conducted. Investigations of the food economy of the fish of McMurdo Sound and a study of the identity, distribution, abundance and ecology of inshore marine vertebrates was carried out, also in the summer season. Studies on the marine fauna and land invertebrates will be made during the winter. Standard surface and upper air meteorological observations are continuing. In the summer of 1959–60 a U.S. traverse party of the Scott-McMurdo complex will perform seismic, gravity, magnetic, and glaciological investigations on the Victoria Land Plateau.

Hallett station.—The joint New Zealand-United States operation of Hallett station is continuing as during the IGY, staffed principally by New Zealand personnel; one civilian meteorologist and Navy aerographers are conducting the meteorological program. Observations in aurora, geomagnetism, ionospheric physics, and seismology are being made. In meteorology, surface, upper air, and radiation observations are being carried out. Biological investigations including microbiological investigations of respiratory infections and of aspergillosis, the fungus disease which attacks penguins in captivity, are now underway. Internal parasites of seals and birds of the Hallett station are being studied.

Scott base.—Through international arrangements, the United States is participating in the scientific work at the New Zealand Scott base. The United States is cooperating in an enlarged auroral program and by making seismic soundings. Small programs of glaciological and oceanographic investigations are also being carried out by U.S. personnel.

Wilkes station.—Cooperative arrangements have been concluded with Australia to continue research programs at the Wilkes station under Australian administration in the fields of aurora, geomagnetism, ionospheric physics, meteorology and seismology. U.S. equipment remains at the station for use by Australian scientists and two U.S. meteorologists are assisting in the program of surface and upper air observations.

A U.S. biologist is conducting an investigation of the sexual and parental behavior and orientation mechanism of the Adélie penguin.

Ellsworth station.—Cooperative arrangements with Argentina have provided for the continuation of the IGY programs of glaciology, auroral studies, cosmic ray measurements, ionospheric vertical incidence soundings and whistler recordings at Ellsworth station under Argentine administration. A U.S. meteorologist is assisting in the regular 3 hourly surface and twice-daily upper air meteorological observations.

Other.—As opportunity permitted, oceanographic observations were made in antarctic waters from ships of Navy Task Force 43. This program included echo sounding and bathythermograph measurements, the acquisition of water

samples down to 5,500 meters for later analysis, and standard hydrographic stations.

A U.S. biologist aboard vessels in antarctic waters collected fish specimens for study of the food cycle of antarctic fauna.

Antarctic Program, 1960

Basically, the Committee on Polar Research believes that an expansion in the level of the U.S. antarctic scientific programs is necessary for future years over that which it has been possible to conduct during the 1959 program. This position is not based upon comparison of the U.S. scientific effort in Antarctica with those of other nations, but simply upon the intrinsic scientific importance of the programs which we feel the Nation is competent to undertake.

The Committee has recommended enlarged programs for 1960 in the Antarctic, particularly in newer fields such as biology, medicine, and geology, as well as by the acquisition of new equipment or the replacement of instruments becoming obsolete. The Committee's specific recommendations for the 1960 antarctic program follow:

South Pole, Byrd and Hallett stations.—The scientific programs at Amundsen-Scott South Pole station, Byrd station, and the joint New Zealand-United States Hallett station are recommended to continue at the same level as during the 1959 U.S. antarctic program, including scientific programs in the disciplines of aurora, geomagnetism, seismology, meteorology, and ionospheric physics. Programs in glaciology and astrodeterminations of the movement of the icecap are also recommended to continue at Byrd station and the South Pole, as well as continuation of the whistler recording programs at Byrd station.

McMurdo Sound.—Continued operation of the surface and upper air meteorological programs is recommended. Major biological and medical programs in the fields of marine biology, botany, zoology, microbiology, psychology are likewise recommended. It is also proposed that a comprehensive program of bedrock and glacial geology be initiated, looking to the systematic expansion of this program in other antarctic regions during future seasons.

Wilkes station.—In accordance with a joint announcement by the Governments of Australia and the United States on the continued operation of the Wilkes station, scientific programs are recommended to continue cooperatively during 1960. The United States should continue to provide facilities, spare parts, and supplies for the scientific program in addition to providing one biologist and two meteorologists.

Ellsworth station.—In accordance with a joint announcement by the Governments of Argentina and the United States on the continued operation of Ellsworth station, scientific programs are recommended to continue cooperatively during 1960. The United States should continue to provide facilities, spare parts, and supplies for the scientific program in addition to providing two meteorologists to assist in the work.

New Zealand Scott base.—Continued cooperation with Scott base is recommended, with the assignment of two U.S. glaciologists, one seismologist, and one oceanographer to winter over at the New Zealand Scott base to participate in the winter scientific program. The glaciologists and the seismologist would participate in the over-snow traverses originating from McMurdo Sound during the 1960–61 Antarctic summer season.

Over-snow traverses.—Two major over-snow traverses are proposed during the 1960–61 summer season.

(i) Originating at the South Pole and proceeding in a triangle in unexplored areas.

(ii) Originating at McMurdo, proceeding over the Victoria Land Plateau in the direction of Wilkes Land.

Other.—Shipboard scientific programs in the fields of oceanography, meteorology, marine biology, and bottom topography are recommended.

Seasonal micrometeorology programs are recommended at the Beardmore Glacier, as a first effort in this region and in anticipation of a future opportunity to establish a full-scale scientific facility.

Similarly, meteorological observations at Kiel Field, near Little America, seem relatively easy to resume and should be undertaken as a first step in reestablishing a major center of scientific activity at Little America. In addition, the program of deep drilling initiated during the IGY in the region about Little America should be continued without interruption in view of its importance in revealing the history of past Antarctic climatic changes.

Assignment of a U.S. meteorologist to the Weather Central in Australia should be continued.

The Committee on Polar Research believes that opportunity should be afforded in subsequent antarctic programs for further enlargement of the scientific work:

(i) The assignment of a vessel, suitable for operation in antarctic waters and made available exclusively for scientific work, is urgently required: such a vessel would enable our scientists, for the first time, to conduct fully meaningful programs in the fields of physical oceanography, marine biology, and submarine geology.

(ii) Immediate planning is recommended of steps which will enable the United States to conduct a program of rocket soundings in the antarctic, not only to investigate the important meteorological phenomena occurring above the heights which sounding balloons can reach, but also to conduct critical measurements in the fields of cosmic rays and auroral and ionospheric physics.

(iii) The United States planning should include the establishment of new year-round scientific stations at new locations; the Committee particularly recommends reestablishment, at the first opportunity, of a full-scale scientific program at Little America, as well as a new station at the Beardmore Glacier.

(iv) The geology program should be greatly expanded with major geological work initiated as soon as possible in areas such as Marie Byrd Land and the Pensacola and Horlick Mountain Ranges, where exploration has originally been made by the United States.

B. The Arctic Scientific Program

In considering the objectives of U.S. science in arctic regions following the IGY, the Committee recognized the existence of a considerably different situation than that which obtains for Antarctica. In the latter region remoteness and inaccessibility require the development and conduct of integrated and coordinated annual scientific programs, correlated with a clear definition of the long-term scientific objectives in each field. In the Arctic, however, a number of institutions, both public and private, are now conducting research programs which, together, constitute quite extensive coverage of some scientific fields. In addition, the Arctic program is not so easily susceptible to organization around specific stations, except at locations such as the drifting stations in the Arctic Basin—nor does this approach appear generally desirable.

Particular emphasis has been placed by the committee upon those elements of the IGY program which are scientifically most important to continuing operation during future years, for example, sustaining our net of IGY all-sky auroral cameras, focusing our programs in upper air research about two or three localities where interdisciplinary attacks can be made on problems in the high atmosphere, integrating the approach to problems in meteorology, oceanography, and glaciology so that a concerted approach is adopted for the understanding of the heat and water budget of this increasingly strategic region.

At the same time we have been conscious of the tremendous lack of knowledge in this Nation about the Arctic Ocean Basin, where systematic scientific investigations have been neglected by the United States until two stations were established on the floating ice during the IGY. Unfortunately one of these stations was recently compelled to close due to the shifting ice, and U.S. science in this region is now reduced to those observations which can be taken on IGY station "B", an ice island. The Committee strongly believes that at least one more station fully equipped for scientific measurements of all types should be established promptly, and we recommend the establishment of a third drifting station at the earliest opportunity.

The recent exploits of the U.S.S. *Nautilus* and U.S.S. *Skate* in traversing under the ice of the polar oceans also opens new doors to science. The committee believes that such important basic scientific information could be gathered by nuclear submarines that these opportunities should be promptly and fully exploited. I should like to stress this point for, while recognizing the cost, here is a tool which rapidly can secure the most important scientific data over a wide expanse in a currently unknown region. The scientific potential is enormous, and the prestige values to this Nation by such achievements, tremendous. I earnestly commend this plan to your attention.

Arctic program, 1959–60

As I have already indicated, the recommendations of the Committee on Polar Research for research in the Arctic have first taken cognizance, insofar as

possible, of research programs already conducted or planned. The recommendations which follow constitute a program which, in our opinion, is scientifically most important to conduct and which, taken with the existing programs of which we have knowledge, comprise an integrated research effort. However, our recommendations for the Arctic do not, except in a few cases, suggest the specific stations at which the research should be conducted.

Biological and medical programs.—Committee recommendations for programs in this field are, initially, quite general as more information concerning prior and present work is considered necessary. However, we have recommended beginning work to systematize zoological and botanical information of life indigenous to the Arctic. Studies are also recommended of the social, personal, and cultural aspects of humans in the Arctic region, particularly with respect to dietary changes and requirements of people living in isolated locales, as well as to the cultural factors important in the development of the Arctic regions. Research concerning adaptation of nonindigenous human populations to the Arctic climate and environment is also recommended.

Earth's crust and core program.—The Committee recommends that major programs in seismology, gravity and geomagnetic investigations of the Artic Ocean Basin be initiated at once from two drifting stations. Submarine geological studies (bottom coring, bottom photography and mapping of the ocean floor) are also urgently recommended. Light aircraft should be acquired to extend the range of these observations and additional coverage should be undertaken during the summer aboard vessels in the Arctic Ocean. Installation of seismographs at Point Barrow, Alaska, and Mould May and Alert in the Queen Elizabeth Islands is also recommended. A basic study of the scope and properties of permafrost in the vicinity of Fairbanks and at locations on the Arctic slope is recommended in order to provide information on which to base a long-range, comprehensive program.

Geodesy and cartography program.—The Committee's initial recommendations in these fields are general, since it appears most desirable to conduct a survey of existing information and future needs. It is recommended, as a first step, that compilation of a map of the Arctic on a scale of 1:3,000,000 be undertaken, and that studies be initiated to define the scope of an Arctic atlas which would contain information on all geophysical features. Coincidentally, a study of the status of geological mapping in Canada, Scandinavia and the U.S.S.R. should be made in order to provide a comprehensive source of material for the atlas and to establish liaison for future cooperation.

Heat and water program.—In glaciology, the initial phase of a several-year program surveying past glaciation, present glaciers, and snow fields of the North American Rocky Mountains is recommended in conjunction with an integrated program to examine the overall heat budget of the Arctic and north temperate regions.

Studies of flow mechanics, petrofabrics and radiation should be resumed on the McCall and Blue Glaciers. IGY sea ice studies should be continued on the drifting stations in the Arctic Basin.

In meteorology, special emphasis is placed upon continuing regular surface and upper air observations from the drifting stations; micrometeorological observations, and special studies of solar and terrestrial radiation, CO_2 content, surface ozone radioactivity and precipitation are also strongly recommended. Use of light aircraft, as already recommended for the crust and core program, is considered most important to report the drift of pack ice and to extend the meteorological studies.

The committee recommends an expanded program of oceanographic investigations in the Arctic Ocean Basin, coordinated with other programs in progress or planned by other agencies. In particular, the use of two icebreakers (and, ultimately, a submarine) is recommended immediately in order to extend studies of the tides in high latitudes, bathymetry, and current circulations in the polar basin. Marine biological and sea floor geological studies are also recommended for inclusion in the ship program.

Upper atmosphere program.—The committee recommends that future programs of research in the upper atmosphere (geomagnetism, cosmic rays, and auroral and ionospheric physics) be directed toward an interdisciplinary attack on these problems at a few selected arctic locations. The region about College, Alaska, is particularly recommended for this program since a substantial program in many fields is already being conducted by the Geophysical Institute, University of Alaska; other suitable centers appear prospective and promising at Churchill and Thule. At College, the committee strongly recommends that

support be provided to continue operation of available instruments: auroral all-sky cameras, auroral patrol spectrographs, auroral radars, auroral photometers and scanning spectrometers, riometers, vertical-incidence and backscatter ionospheric sounders, whistler and VLF recording equipment, and rapid-run magnetometers. This centralization of equipment, so important to interdisciplinary attack on the important problems of the upper atmosphere, cannot be duplicated elsewhere in the Northern Hemisphere and should, at all costs, be maintained. Moreover, opportunity exists to add a neutron monitor to this facility as well as research in cosmic rays using high altitude balloons; the Committee recommends support for these programs.

The Committee also strongly recommends continuation of the IGY program of rocket launchings at Churchill, Canada, further to investigate the structure and composition of the atmosphere at high latitudes.

Continuation of cosmic ray observations at Thule, utilizing the existing meson telescope and neutron monitor, is strongly recommended. In addition, the Committee strongly supports plans for the continued operation, by military agencies, of programs at Thule in ionospheric physics, auroral physics, and airglow measurements.

A program to continue all-sky camera observations of the aurora at selected existing IGY locations is most highly recommended.

International collaboration in Arctic research

Finally, let me say a few words about international activities in the Arctic. While the ICSU has not considered that the establishment of a special ICSU committee is required to effect international coordination of scientific programs in the Arctic, international collaboration will continue. This assurance is already afforded by the International Geophysical Cooperation–1959 (IGC–59) program established by the ICSU, to which it is expected that all nations bordering the Arctic will adhere. Although we have not received information concerning IGC–59 programs of any of the nations concerned with Arctic research, except that of the U.S.S.R., there is sound reason to believe that a large international program will be undertaken under the auspices of IGC–59; the U.S.S.R. has already announced that it will continue its full IGY program without change during 1959. As during the IGY, data from the IGC–59 program will continue to be interchanged internationally and deposited in the respective world data centers.

Statement of Dr. Harry Wexler Concerning Meteorology and Glaciology Programs

Dr. Wexler. In view of what happened yesterday, I threw away my notes which were supposed to be supplementary to my testimony, which, with the Chairman's permission, I hope will be inserted in the record.

(Dr. Wexler's statement follows:)

Mr. Thomas, members of the committee, I am very happy to have the opportunity to discuss with you the IGY programs in meteorology and glaciology. Dr. Revelle, in his statement on the oceanography program, has covered part of what we call the heat and water budget of the earth. I will tell you something of the glaciological results and, of course, also of the work that I am most interested in, the meteorological program.

I. Meteorology

The international IGY program in meteorology was motivated by the desire to obtain as complete a description as possible of the atmosphere on a day-to-day basis so that scientists could analyze the changing patterns of the atmospheric circulation. Among other things it was hoped to assist in the development of new theories and the refinement of existing theories, and to help explain some of the little understood happenings in the atmosphere. According to recommendations developed at international meetings, countries were urged to take special efforts to reach very high altitudes with meteorological sounding balloons and to establish new stations in areas where meteorological data were missing. Some special programs were also recommended, for example, the study of the incoming solar radiation and the outgoing terrestrial radiation,

and the distribution of important minor constituents of the atmosphere like carbon dioxide and ozone.

As you know the U.S. Weather Bureau network of balloon sounding stations was rather extensive even before the IGY. The addition, however, of just a few new stations for the IGY—two in the Arctic Basin, seven on the Antarctic Continent, and, in cooperation with South American countries, five on the west coast of South America— the U.S. meteorological coverage was greatly extended. I am very happy to report that the stations have all operated on a very high level of competence and reliability. The five stations in South America have had a tremendous impact on the increase in knowledge of the atmosphere in this region and have benefited not only the countries in which they are located but also various commercial services as, for example, the airlines. We are most pleased to report that these stations, having been established for the purpose of the IGY, will continue to operate on a cooperative basis with new support from other agencies in the United States. This opportunity afforded to the meteorological services of the South American countries to train additional personnel may also, it is hoped, contribute to the strengthening of these services in the future.

Prior to the IGY emphasis on obtaining very high altitudes, meteorological soundings using 600-gram balloons averaged about 71,000 feet in altitude. Even before the IGY, however, the U.S. Weather Bureau, the U.S. Air Force Air Weather Service, and the U.S. Army Signal Corps cooperated with balloon manufacturers to increase the performance of these balloons. During IGY, an improved 600-gram balloon was used. This balloon had an average bursting altitude of over 80,000 feet and quite frequently reached altitudes of approximately 100,000 feet. At certain stations for soundings at noon, Greenwich time, special 800-gram balloons were employed. Soundings using these special balloons averaged over 90,000 feet in height and quite frequently attained altitudes in excess of 100,000 feet. The high altitude program was very successful and provided important data on the high stratosphere circulation. It is expected that most countries, and certainly the United States, will continue to use these higher performance balloons, for our present scientific studies of the atmosphere, as well as aircraft operational requirements, demand more and better data from these very high levels. In addition to the extensive measurements of temperature, pressure, wind speed and direction, cloud cover, and precipitation, in the synoptic aspects of the program, some special studies provide a great deal of very important information to the meteorological scientists.

Ozone

One of the most important minor constituents of the atmosphere is ozone, a variety of oxygen which has very important properties. Normal oxygen molecules absorb ultraviolet radiation in the high atmosphere to form atomic oxygen. These free atoms of oxygen collide with oxygen molecules to form ozone, and ozone in the absence of sunlight decays slowly to normal oxygen with the release of energy. Ozone has a short lifetime in the photo-equilibrium layer (25 to 30 miles) but at 12 miles ozone may persist for 3,000 days. So we might say that ozone is a reservoir of energy in the high atmosphere, the effect of which on the atmospheric circulation may be far greater than its low concentrations may indicate.

At Little America Station both surface concentration and total ozone in the atmosphere were measured. The total ozone concentration was measured by observing how much of the sun's ultraviolet radiation penetrated to the surface. In the polar winter, sunlight reflected from the moon was used to measure the ozone concentration although, of course, this method is not as sensitive as observing the solar light directly. The seasonal variations of ozone in the Antarctic differ from what would be expected from casual consideration of the photochemical mechanism of ozone formation. Since ozone is only formed in any quantity in the presence of ultraviolet light from the sun, it might be expected that in the long polar night the ozone would gradually decrease. However, the opposite is found. There was a rapid rise of surface ozone concentration in March and April and a slow decrease in September after the sun returned. The total ozone content also showed a maximum in the dark hours. The explanation of this anomalous behavior must be sought in the study of vertical and horizontal circulation systems carrying ozone poleward from sunlit regions. Perhaps, on the other hand, some generation of ozone occurs during the polar winter by auroral activity.

At the Weather Bureau station on the slopes of Mauna Loa in Hawaii the ozone showed a daily variation related to the noctural descent of air from upper layers and daytime ascent up the heated mountain slopes.

Atmospheric purity

Specialized studies of solar radiations at certain key stations have turned up some interesting information on the clarity of the atmosphere. It turns out that the atmospheric clarity at Little America (at sea level) and at Mauna Loa (13,000 feet elevation) is very high and about equal, while at the South Pole the sky is even clearer. The atmosphere in this region of the world may be the clearest and most transparent anywhere. Preliminary results from station Alpha in the Arctic Basin indicate that long wave radiations from overcast skies are an important factor in the melting of surface ice. It was observed that melting proceeded much more rapidly when the sky was overcast rather than clear and sunny; refreezing may actually occur under the clear summer sky because of increased radiation to space through the clear atmosphere.

Carbon dioxide

Air temperature in the lower level of the earth's atmosphere is extremely important to man and it is probable that the amount and distribution of carbon dioxide in the atmosphere plays an important part in regulating these temperatures. One of the special projects of the IGY was to try to determine the amount of carbon dioxide in the atmosphere so comparisons could be made with past determinations (which are, however, not as reliable as present measurements) and with measurements to be made in the future. By these means we will be able to determine if and by how much the concentration of carbon dioxide is changing as our industrial civilization pours millions of tons of carbon dioxide yearly into the atmosphere. It was also decided to measure the carbon dioxide in the atmosphere at sea, and in sea water to attempt to study the mechanism by which carbon dioxide is absorbed by sea water.

The U.S. Weather Bureau and the various oceanographic institutions cooperated in obtaining observations on carbon dioxide concentrations. Measurements made in the Arctic by U.S. and Scandinavian scientists indicated a great fluctuation of carbon dioxide concentration but surprisingly enough, when the oceanographers took their instruments to sea they found that measurements over thousands of miles of open sea water showed variations of only a few percent. Continuous measurements of pure air at Little America showed the smallest variation yet obtained, over any period of observation about 0.3 percent. A slightly larger variation of about 1 percent was observed at Mauna Loa.

During August of 1958, scientists of the Woods Hole Oceanographic Institution conducted some observations of the vertical distribution of carbon dioxide in the area of Nantucket Island. Their soundings showed marked variations of carbon dioxide with altitude and it was also noticed that a minimum was sometimes developed between altitudes of 1,000 and 3,000 feet. No particular correlations were found between the carbon dioxide values and the various meteorological parameters; however, it was noticed that vertical carbon dioxide concentrations persisted whenever meteorological conditions in the same area remained unchanged.

Scientists of the Agricultural and Mechanical College of Texas observed that during and after a violent rain squall, the carbon dioxide in the water and atmosphere changed markedly. Twenty-four hours after the squall, the carbon dioxide in the water had not returned to normal while the atmospheric carbon dioxide had returned to its original level in about 6 hours.

Samples of air were taken at selected stations in the Arctic and Antarctic and during aircraft meterological reconnaissance flights of the Air Weather Service. These samples are being analyzed at Scripps Institution of Oceanography where a special laboratory was constructed to provide for an absolute calibration of all of the carbon dioxide instruments.

Nuclear radiation

Data collected along the 80th meridian for the measurements of nuclear radiation show the north-south spread of radioactive debris from tests conducted during the IGY. The radioisotope analysis has revealed the strontium 90 in the ground level Southern Hemisphere air to be much older than in the Northern Hemisphere. Further, the air concentrations of strontium 90 Northern Hemisphere air is about five times greater than in the Southern Hemisphere. Since the origin of almost all of the strontium 90 in both hemispheres is from the stratospheric reservoir, these facts will assist the meteorologist in propounding theories of stratospheric circulation and exchange mechanisms. North-south profiles of the monthly average gross fission products from U.S.S.R. tests show a rapid southward spread into Southern United States. On the other hand,

essentially negligible amounts of tropospheric fission products have mixed into the Southern Hemisphere ground levels from tests in Nevada and the U.S.S.R. fission products of the Hardtack test series conducted at 11° N. on the other hand, were found in readily measurable quantities in the Southern Hemisphere.

World weather maps

One of the plans of the IGY is that daily weather maps of the entire globe will be prepared from the IGY observations. The U.S. Weather Bureau will prepare maps for the Northern Hemisphere; the South African Weather Bureau, the Southern Hemisphere maps; the Federal (West) German Weather Service, the equatorial maps. It is planned that the maps will be drawn for two levels, sea level and 500 millibars (about 18,000 feet).

Stratospheric meteorolgy

The worldwide radiosonde data upon which stratospheric research depends, are now being assembled on microcards in Geneva, Switzerland, for distribution to research meteorologists. Never before have complete data for so large a portion of the globe been accessible to these scientists. Their work will be accelerated by the U.S. Weather Bureau program of synthesizing data by analysis of pole-to-pole cross sections and daily hemispheric 100-millibar, 50-millibar and 10-millibar constant pressure charts. The resulting analyses will be published in convenient booklet form. Experimental 10-millibar charts that, for the first time, represent daily flow at the 100,000-foot level over a large area have been prepared and put to use by several scientific groups concerned with very high level flight in the atmosphere.

The major upheavals of stratospheric circulation in each hemisphere usually occur but once or twice in a single year. This phenomenon as it occurred in the Northern Hemisphere differed in some important respects during the two winters of the IGY and much depends on the observations from additional winters. Discussions among meteorologists have also been stimulated by preliminary information revealing that the development of wavelike perturbations within stratospheric jetstreams of the north polar region are fundamentally different from those of the south polar region.

Results of earlier antarctic expeditions revealed that the thermal structures of the arctic and antarctic stratospheres were quite different. This difference was especially noted in the winter months. During this season the antarctic stratosphere was found to be, on the average, 20° F. colder than arctic stratosphere. A number of hypotheses were advanced to explain this difference, but the amount of data available from the Antarctic was too limited to determine which, if any, of these were correct. Now that upper-air data are being obtained for the first time from the interior as well as the periphery of the Antarctic Continent, it appears that the winter antarctic stratosphere is more effectively "sealed off" than is the arctic stratosphere. The arctic circulation is apparently more unstable than that found in the opposite hemisphere. This instability permits warm air to invade the arctic stratosphere during midwinter and cause the normal wintertime cooling to be reversed, resulting in anomalous temperature rises. The stable circulation in the Antarctic effectively prevents this anomalous wintertime stratospheric warming and the temperature falls quite steadily through the autumn and winter months at an average rate of 0.5° F. per day.

To quantitatively determine the basic causes for the variances in the stability of the polar-stratospheric circulations will require a continuing program of high-altitude, high-latitude observations. This data may then be fitted into mathematical models for analysis by high-speed electronic computers.

Meteorological observations in the Arctic Basin

Two extremely important meteorological stations were those established in the Arctic Basin. Station Alpha, at which high-altitude wind, pressure, and temperature observations were taken, was constructed on a floe imbedded in the arctic icepack; station Bravo, where an intensive micrometeorological program including vertical temperature gradient soundings with tethered balloons and heat flux and solar radiation observations were undertaken, was located on the floating ice island, T–3. In August 1958, the high temperature at station A was 37° F. and the low was 23° F. By October the average temperature had dropped to just under 20° F., and a low was recorded of almost —31° F. During the summer months the high-altitude balloons performed exceptionally well, with average heights in July and August in excess of 110,000 feet, but in October, with much lower temperatures, the highest altitude reached was only 88,000

feet. At station Bravo the high temperature in August was 40° F. and, as usual, there were many problems because of the melting of the ice—leaving the buildings on 6-foot-high pedestals of ice—and the formation of lakes. The October average temperature decreased to 5° F. and a low was recorded of −33° F.

Unfortunately, late in October 1958, the pack-ice conditions at station Alpha began to deteriorate, and a study by station personnel over the whole period of occupation of the station showed that since the original occupation of the site in the spring of 1957, there had been a great change in the size of the floe. It was found that an open-water lead had separated approximately 40 percent of the remaining floe on the east and southeastern side, that there was another separated portion on the western side, and that one long crack extended toward the southern part of the floe. Finally, by November 2, the runway had separated into two parts; and the floe had decreased its size to the point where it was decided to end operations.

On November 7, 1958, the U.S. Air Force evacuated the personnel from station A and recovered most of the scientific data. It was not possible, however, to evacuate some of the bulky ice and water samples which IGY scientists had collected and most of the equipment on the floe.

Antarctic weather

Each time I have appeared before this Committee I have been able to report a new record low temperature and I shall not disappoint you this time. As you know, for many years Siberia had the lowest temperatures on record, −90° F. The −102° F. temperature observed at our IGY South Pole station gave the United States its brief moment of meteorological glory in 1957 and early 1958. But in July and August of 1958 the Soviet IGY Vostok and Sovietskaya stations, 2½ miles altitude, on the high, icy plateau of east Antarctica, broke this record and the new records again and again, until Vostok won with a temperature of −125° F.

Here is a brief summary of some interesting information which we received from the various stations in their regular reports.

Amundsen-Scott (South Pole) station.—At the South Pole station in July the average temperature was −67° F. and a low was recorded of −96.8° F. Aloft, on July 16, a radiosonde recorded what may be the world's lowest atmospheric temperature, −93° C. (−135.4° F). July was also a record month for wind speed, but the meteorologist in charge reported that at the surface it was the warmest winter month of the 2 years of record. During July the average height for the sounding balloons was 55,000 feet.

By August the average temperature had dropped to −79° with a low temperature of −100° F. The atmosphere continued to cool in the lowest layers. The low part of the stratosphere, however, showed a termination of cooling, but cooling continued in its upper layers. The stratosphere above the 50-millibar level showed cooling for 8 continuous months. During August the average altitude reached by the meteorological sounding balloons was 50,000 feet.

In September the lowest temperature was −101.7° F., equaling the previous minimum for 1958 that was measured in June. However, the average temperature in September was −69° F., 10° warmer than that of August. With the return of sunlight to the stratosphere to provide some warmth for the meterological balloons, sounding heights improved and the highest altitude reached was 83,000 feet. In October and November considerable warming was experienced at the pole both at the surface and aloft, the average temperature near the surface in November being only −37° F. On October 24, a balloon sounding showed that a temperature of plus 30° F. existed at a height of 116,400 feet while surface temperatures were about −50° F. This particular sounding set an altitude record in the Antarctic of 122,200 feet.

To give you an example of the special work carried out at the South Pole, almost 200 wind profiles were obtained each month using a micrometeorological mast with special anemometer cups at several levels and thermocouples for careful measurements of vertical temperature gradients. Such information not only gives in detail the various conditions to which a man might be exposed, but it also provides necessary information for further scientific studies of the process whereby heat is exchanged between the air and the snow surface.

Particular attention was given the relation of radiant energy exchange and sensible heat flux with conditions of extreme cold, i.e., temperatures near

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—100° F. During a clear period, in mid-September, for example, when the surface temperature averaged —99° F. for 6 hours, the snow surface was losing 50 percent more radiant energy to the atmosphere than it was receiving. It was found that this energy loss was not made up by additional cooling of the snow surface, but by fluxes of sensible heat from the relatively warmer layers just above and below the snow surface. During this particular case, 48 percent of the energy came from the reservoir of sensible heat under the snow surface where the temperature remains near —60° F., and 52 percent of the energy came from the warmer air of the surface inversion. During the winter nights, clouds, which were invariably warmer than the snow surface, transmitted so much energy to the surface, that it would rapidly warm up as if the sun had suddenly appeared.

Byrd station.—At Byrd station in the interior of the continent temperatures were also quite low. In July the average temperature was —40° F. with a station record low of —82° F. In August the average temperature decreased to —44° F. and a low of —80° F. was recorded. The first sunrise occurred on August 25 with 95 minutes of sunlight. By October the average temperature warmed up to —22° F. and the recorded low was —49° F. Large accumulations of snow with drifts hampered observations, particularly balloon soundings. The snow had piled up several feet higher than the roof of the balloon shelters, and each day it was necessary to shovel the snow away from the trap door on top of the building. The endless drift of snow into the interior of Marie Byrd Land, where a deep trench exists in the snow near the foot of the Horlick Mountains raises a question as to why in the milleniums of wind drift this trench has not filled.

Little America station.—At Little America average temperatures in July, August, and September were —35° F., —32° F., and —32° F., respectively; low temperatures were —70° F. in July and August and —73° F. in September. The latter occurred after the return of the sun and after the record maximum of plus 22 was recorded for August, normally one of the coldest months with temperatures well below zero. The warming trend of Little America temperatures, amounting to nearly 5° F. since 1812, continued into 1958.

Ellsworth station.—The Ellsworth station, although located on the opposite side of the continent from Little America has a very similar physical location. Both of these stations are at about the same geographic latitude (78° S.) and elevation above sea level (about 145 feet), and both are situated on a floating ice shelf on the edge of a major sea. These two seas, the Ross Sea at Little America and the Weddell Sea at Ellsworth form embayments in the Antarctic Continent and are preferred regions for cyclonic storms. All of these similarities result in both stations experiencing nearly the same average weather conditions. The average temperature for 1958 at Ellsworth was —10.5° F. while at Little America it was — 9.7° F. The coldest and warmest temperatures recorded during 1958 at Ellsworth were —68.1° F. on May 13 and +34.0° F. on December 31, compared to the extremes at Little America of —72.9° F. on September 10 and +33.1° F. on January 4. Both of these stations along with Byrd Station have proved to be very important in mapping the paths of cyclonic storms across west Antarctica, which are believed to be responsible for the heavy snow accumulation in this region.

Hallett station.—The Hallett station, located on the northwestern edge of the Ross Sea and about 300 miles north of McMurdo Sound (and on the direct air route from New Zealand to McMurdo) has provided important information on the storms entering the Ross Sea from the west. These major storms pass Hallett station at the rate of about four or five per month with the most severe of storms rivalling the intensity of a Florida hurricane. The most severe storms occur during the months of March through October. During each of these months in 1958, an extreme wind speed in excess of 50 m.p.h. was recorded at Hallett station with the highest wind being 85 m.p.h. during a June storm. During this particular storm, the temperature rose to +14° F. The coldest temperature recorded during 1958 was —39° F. on August 22.

This combined weather and emergency station more than paid for itself one day in October 1958 when, because of poor weather at McMurdo Sound, 5 aircraft, with 52 crew members aboard, made emergency landings on the smooth bay ice near the station.

Wilkes station.—At Wilkes station during 1958, as in 1957, the warmest climate of any of the U.S. stations was experienced; this station is considered by personnel at other stations as situated in the "banana belt." This is due, of course, to the fact that its latitude is only 66°16′ S. or almost 15 miles north of the

Antarctic Circle. Although the summers are relatively cold with average monthly temperatures for December, January, and February being about +28° to +32° F., the winters are mild. During 1958, the coldest winter month was June with an average of —6.3° F. The absolute minimum temperature for Wilkes station of —36° F. was recorded on July 27, 1958. But what the station lacks in frigid temperatures it more than makes up in wind. The wind cascading down the nearby ice cap often reaches speeds greater than 100 m.p.h. The commencement and cessation of these strong winds are abrupt and are usually accompanied by simultaneous large rises and falls in pressure. An analysis of one of these occasions found the pressure suddenly dropping about 2.5 mb. with an increase in wind speed from 10 to 50 m.p.h. Two hours later the pressure just as rapidly jumped up 3.5 mb. and the winds immediately slackened to 10 m.p.h. A special high speed barograph was used to record these rapid changes in atmospheric pressure.

IGY Antarctic weather central.—IGY weather central operations at Little America continued through 1958 in the same manner as was reported to this Committee last year. During the IGY the staff, including meteorologists from Argentina, Australia, France, New Zealand, South Africa, the United States, and the U.S.S.R. have worked most successfully together. Research papers on antarctic meteorology have been published. Forecasts were issued for aircraft, field and ship operations. Map analyses and weather data were broadcast from Little America four times daily. Many of the special weather studies begun in 1957 were continued and expanded in 1958. Vertical time-sections and cross-sections were prepared to analyze the detailed structure of the storms moving over Antarctica. Eight papers by U.S. meteorologists will be presented at an Antarctic Meteorological Symposium opending today at Melbourne, Australia.

The weather central operations were terminated with the closing of the Little America station in January 1959. However, the work begun there will be continued by an International Antarctic Weather Central to be located in Melbourne, Australia. It is expected that an American meteorologist will be assigned there to assist in the preparation of forecasts and analyses, which will be useful operationally, and also in the study of world weather.

II. Glaciology

At our discussions with this Committee last year, Mr. William Field of the American Geographical Society, described for you the progress in the first year of the United States IGY glaciological program. The first season of station glaciology and oversnow traverses in the Antarctic provided significant and hitherto unavailable information on the thickness of ice in the Antartic and of the nature of the underlying terrain. This season's traverses have again set out, but at this time there is only a small amount of preliminary information available. All together, the past 2 years have seen over 10,000 miles of surface and airborne traverses made by nine separate groups of United States IGY scientists operating mostly in areas hitherto unknown.

Antarctic deep drilling program.—The deep drilling program at Marie Byrd station was successfully completed by the U.S. Army SIPRE drill teams and temperatures and cores were obtained to a depth of 1,013 feet. Some preliminary analyses of the cores were done in the Antarctic: for example, they were placed in a trough and viewed from above with the aid of a light source under the core. The exact positions of the various layers of ice were then obtained by measuring with tapes, and photographs of the layered structures were taken. It was found that distinctive layers could be obtained to the depth of 400 feet, farther on the cores did not show any visible stratification. Some small samples were removed from the core for determination of the density. Density increased from about one-half gram per cubic centimeter near surface to over nine-tenths gram per cubic centimeter at a depth of 720 feet. The cores have been transported to the laboratory at the U.S. Army Snow, Ice and Permafrost Research Establishment (SIPRE), Wilmette, Ill., where scientists will complete the density studies and analysis of the ice crystals, included foreign particles and trapped gas bubbles, and will make measurements of tritium and other radioactive substances. Measurements of the ratios of the oxygen isotopes 16 and 18 will be carried out at the California Institute of Technology. This work will help identify the winter and summer layers in the deep parts of the core.

In the meantime, the hole in the ice itself at Byrd station remains an important tool for measurements of temperature at various depths. Beneath the station the ice was found by seismic soundings to be about 10,000 feet thick, extend-

ing 5,000 feet below sea level. The snow at 150 feet depth, which was laid down approximately 150 years ago, is warmer than the surface by 1° F., apparently a result of a slightly warmer period which occurred during the past century, the warmth from which is propagating downward. Below this warm layer the temperature decreases at such a rate, that if extrapolated deep down in the ice, would indicate that the snow was deposited at a time when the climate was several degrees colder than now. Plans are underway to drill a hole all the way through the ice to observe how far down the temperature decrease persists and at what level it begins to increase with depth—as it should under influence of the slow influx of heat from the earth's interior over the millenniums.

Special microphones were lowered into the hole to receive sound signals from distant explosions to record the speed of waves so important in the study of ice structure and the thickness of the earth crust. The hole will be observed over a period of many years to determine how it deforms under influence of the slowly moving Antarctic ice.

The drill rig was moved by tractor train to Little America and on October 31, 1958, drilling was started on the Ross ice shelf. Drilling was completed on December 17. The first core was taken at a depth of 22 feet, with loss of only 1 percent of the total core. Layers of foreign matter were observed at 580 feet, 730 feet, and 744 feet. The first of these was identified as probably volcanic ash. There was no evidence of saline ice in the bottom of the hole, but the drilling was terminated at 836 feet to prevent possibility of the drill bit breaking into a pocket of brine and freezing in. The temperature at 818 feet was 24° F., or 5° below the freezing point of sea water indicating that there was only a few feet of ice left at the bottom of the hole when drilling was stopped.

Antarctic traverse program.—On November 1, a traverse party left Byrd station to explore the area around the Horlick Mountains in the direction of the pole. By December 31, 357 miles were covered, and the party returned on January 21, 1959. In the Horlick Mountains, petrified tree remains, including one section 12 feet long, and leaf fossils were discovered in sedimentary layers of sandstone, shale, and coal.

On October 31, the glaciological traverse party left Ellsworth station destined for Byrd station and arrived on January 8, 1959, after crossing most of west Antarctica. Seventeen seismological and glaciological stations were occupied and 1,250 statute miles were covered. Eight hundred miles were traveled before the first mountains were seen. Maximum ice thickness of 12,000 feet was found in the area of 80°35′ S. and 114°47′ W.

A topographic and geologic survey reconnaissance was extended to a previously unvisited area south of the Windmill Island area, near the Wilkes station. A 100-foot raised beach was surveyed. Ice surveys revealed great differences between some areas of stagnation and the nearby Vanderford Glacier which advances several feet per day. In contrast to the normally negative regime—that is, where the ice is slowly retreating—a small shelf 1 square mile in area was found where excessive local precipitation is nourishing the ice. Evidence was found of various fluctuations in the ice regime since the last major glaciation. Samples were blasted from undisturbed areas for isotope dating.

The traverse from Little America, led by Mr. A. P. Crary, traveled to the Victoria Land Plateau, reaching their farthest point west by January 8, 1959; the party returned on January 31 to McMurdo Sound. Twelve seismic stations were occupied, and it was found that although reflections were poor from the bottom of the ice, the values obtained suggested land at sea level under the plateau ice. Cores of ice were taken as well as samples for later analysis for tritium and oxygen isotopes. Stakes were set in the Skelton Glacier about 90 miles south of NAF McMurdo for future observations of accumulation and motion of the ice.

Northern Hemisphere program

Work was completed at the Blue Glacier in the Olympic National Park in the State of Washington. The scientific party occupied this station until late in 1958 when they completed their series of observations. The data is now under study at the University of Washington and promises to become an important milestone in the study of glaciers. The scientific program at McCall Glacier in Alaska was similarly completed and the data is now under study. A special analysis project was initiated at the Ohio State University under the direction of Professor Goldthwait. There, the glaciologists returning from the antarctic traverses and stations are studying their data with the full benefit of the association with this distinguished academic institution.

The Arctic Basin ice studies

Station Alpha.—It was noticed that the summer of 1958 was a season of very heavy ice loss. The 1958 ablation season (during which snow and ice were removed) was 3 months longer than in 1957 and twice as much ice was lost than in the previous year. The amount lost, however, was not equal to the accumulation during the previous winter. Dozens of ice cores were taken from the pack ice and an extensive program of mechanical study of the ice was accomplished. In September 1958 it was noticed that cooling began in the upper layers of the ice while the lower layers still showed warming. It was not until October that cooling was found at all layers. One of the most interesting occurrences during the summer at Station Alpha was the visit to the station of the nuclear-powered submarine U.S.S. *Nautilus*. This accomplishment opens up a whole new vista of possibilities of scientic exploration of the Arctic Basin, its floor, and the waters of the Arctic Ocean.

Station Bravo.—At station B the ice structure was studied and the various levels of the pack ice with respect to the island surface were recorded. IGY scientists from Argentina carried out studies of ice structure and properties at station B during the summer.

INTERPRETATION AND IMPLICATIONS

Studies of meteorology, oceanography, and glaciology, although dealing with different scientific disciplines, are related by common interests in several things: First, water, of course, is a principal element in these studies, in liquid form in the oceans, in solid form as ice, and as water vapor in the atmosphere; second, these sciences deal with phenomena close to the surface of the earth and, therefore, are of great interest and importance to man and his civilization; and third, the sun provides the energy to link together the world's ice, liquid water, and water vapor in a ceaseless exchange. Perhaps one of the most significant results of the IGY has been the bringing together of the scientists interested in these areas of research, because it is only by the complete study of the heat and water budget of the earth that better understanding will result.

Meteorology is benefiting enormously from better data obtained from the surface and higher atmospheric levels and, as a result of the IGY program, of the completely new data furnished by all the IGY stations in the remote and formerly inaccessible areas. The data from hitherto unknown portions of the earth's surface has great importance in filling the gaps in pre-IGY meteorological coverage. To improve forecasts, and to make them more extensive in time and space, additional data from widespread areas on the earth's surface are required. We also find that observations of events in the higher regions, the stratosphere, may be required to increase our understanding of weather in lower regions, the troposphere. Much more work, of course, needs to be done in examining our observations, but the IGY has already made possible systematic study of very high altitude disturbances and the completion of weather maps at surface and upper levels for most of the world.

The special meteorology programs are also providing a significant return of scientific information. Studies of solar radiation and complete energy balance of the earth will be of the greatest importance in studying the general circulation of the atmosphere. The increased emphasis on carbon dioxide and ozone has produced results which indicate aspects of the circulation which will require increased attention in the future. The study of the distribution of airborne isotopes is also yielding data on circulation phenomena not possible by any other known method. We have also laid to rest some incorrect theories of the antarctic air circulations, while at the same time discovering new features of that atmosphere which are of interest because of their contrasts with the artic circulations.

The glaciologists have become partners of climatologists, for they have opened up a frozen storehouse of information on the past climate of the earth and its fluctuations by their explorations and probing into the interior of the great ice sheets. Of course, the glaciologists have also increased trenmendously their body of knowledge of glacial behavior itself: the interaction between the ice and atmosphere, the ice and the oceans, and the behavior of a huge mass of ice as a mechanical and thermal system.

One of the valuable byproducts of the IGY effort has been to bring to the attention of scientists previously engaged in other work, the attraction and opportunities available in geophysics. Many competent young experimental scientists and students have engaged in geophysical activities for the first time

through the opportunities created by the IGY. This is indeed a very important aspect since, among other things, the IGY has shown us how much more needs to be done in the coming years while at the same time it has helped to create the kind of exciting and stimulating atmosphere which attracts the interest of young people in schools.

Dr. WEXLER. First let me say we did not time this launching yesterday to agree with this hearing, although we are very glad it did happen.

Mr. THOMAS. If you did, more horsepower to you.

Dr. WEXLER. Although Dr. Reichelderfer came very close to it in an article which appeared in the New York Times yesterday. He called me up a few minutes before the launching. I was in the NASA control room, and he said, "Tell the people we didn't try to steal their thunder." I said, "Don't apologize. It might prove to be a good tradition."

What we get from a more sophisticated version of the satellite now flying above us will be a photograph of the earth's surface somewhat similar to this remarkable picture that was put together as a mosaic 4 years ago when a minor hurricane, aloft and out of ground, actually sneaked by our observing network, big gaps of our observing network in the Gulf of Mexico. It entered Texas in the lower Rio Grande Valley. It so happened that on that very day a rocket was being launched at White Sands with a camera and took pictures as the camera rotated. One hundred and seventy pictures were put together giving this view.

When this was done, the people at the Naval Research Laboratory, with whom I had been in contact before, called me up and said, "You had a hurricane down in Mexico, October 4, 1954."

I said, "No, we didn't have any such thing. We had some showers, squally weather, but no hurricane."

They said the developed picture showed a hurricane, whirlpool clouds very similar to the one you people talk about as determined from radar. I went down to take a look at the picture and said, "It does look like a hurricane." We have seen these on radar, spiral nebulae that the astronomers see, rotating into the center and the more we looked into it, the more we were convinced that there was something aloft which we did not suspect from our sparse ground observations in that area.

Further study revealed that there was indeed a storm in the lower Rio Grande, and this is White Sands here, El Paso, Mexico, Gulf of Mexico. We are looking to the southeast, Corpus Christi, and in the lower part of the Rio Grande Valley was the storm that moved up the valley, gave Roswell, N. Mex., a very heavy rainfall, curved, headed toward Chicago, gave them flooding rains, which actually flooded the basement of the Chicago Tribune, and ruined tens of thousands of dollars worth of newsprint.

Mr. THOMAS. At what altitude were the pictures made and at what altitude was the storm?

Dr. WEXLER. The picture was taken from about a hundred miles.

Mr. THOMAS. A rocket from the Weather Bureau?

Dr. WEXLER. It was a regular rocket of the Aerobee type that the Naval Research Laboratory has been sending up for years; a hundred miles above the earth. The storm was perhaps 5 to 8 miles above the surface, way, way down, so we are having a picture look-

ing down and as such we get a bird's eye view of the weather that we haven't been privileged to look at. We are like ants crawling on the surface and trying to piece together bits of information to give us a mosaic of the weather as it actually occurs. Here, now, for the first time, the satellite gives us an observing platform of global extent, in keeping with the global nature of the atmosphere and the storms that knows no boundaries.

Of course, the present satellite does not have cameras. It has photocells. It is something like trying to take a picture with the light meter, piecing together the light and dark instead of using a camera.

That is what we will get out of the present satellite, but it will give us some real data to work with from a height between 335 miles to 2,050 miles, much higher than this. It will give us a much broader area, from 34° north to 34° south and, therefore, it will prepare the way for our experience, knowledge, dealing with more sophisticated and elaborate instrumentation which we hope subsequent satellites will have, not only for the tropical belt, but for the whole world.

This is, I would think, one of the most significant facts IGY has had on meteorology. This is not to say the satellite will solve all problems or replace the observing systems. It will give us a global view, interrelationships of Northern and Southern Hemispheres, polar regions, where we have a few observations, but we will still need the very detailed reports, which we can only get from the surface, necessary for aviation, agriculture, and other purposes. We think that having the data now from portions of the atmosphere, we have never had before, that we will be able to truly examine world weather on a daily basis and learn a lot more about how the atmosphere works and, in so doing, improve our short-range forecasts and extend our forecasts to the future.

FUTURE SATELLITES

As I mentioned in previous hearings, meteorologists have not been able to explain why we have these unusual spells of weather. One year we have a drought, next year we have floods in the same area. We tried to explain these based on Northern Hemisphere weather and essentially low-level observations. We haven't succeeded. The IGY has lifted our booms up much higher, has given us a satellite which will now give observations from the entire world in the next few years and, in so doing, it gives us a lot more opportunity to explore these very unusual spells of weather that affect the entire Nation's economy and welfare.

This is the main impact that IGY has brought to meteorology and this, of course, will develop to such a point that I can envisage a system of meteorological satellites, perhaps six or eight of them simultaneously orbiting the earth, most of them from pole to pole on various meridians and perhaps one or two around the equator; in so doing, observing each and every significant cloud area on earth continuously, and interpreting those cloud observations in terms of significant weather and the motions of storms.

I believe this is not very far off and I think it will greatly improve the service that meteorologists can give to the public in the practical sphere and greatly improve our understanding of the atmosphere.

Mr. THOMAS. Doctor, will you let me interrupt you there? You made one statement that excites my imagination. What connection is there between storms and clouds?

Dr. WEXLER. Generally speaking, to have a significant storm you must have clouds. The heat of condensation, which is released by water vapor as it condenses to form clouds, is one the principal sources of energy of storms. You can have occasional winds going down mountainsides, sand storms in deserts, which are not associated with clouds, but most storms have typical clouds. For example, this whirlpool type cloud is a rather typical characteristic of hurricanes with the arms winding right into the storm. Another type of cloud would be characteristic of a cold front—a long line of clouds extending a few thousand miles, with striations and cellular occurrence which would be individual thunderstorms, squall lines and even tornadoes imbedded in the individual storms.

Meteorologists have developed experience over the years in interpreting clouds in terms of storms, but we have never had the unique view of looking down that the satellite will give to us.

SATELLITE WEATHER MAPS

We are quite confident, in fact, on the basis of experiments we are now carrying out, that if we have cloud observations of this type we can draw a weather map of a rather rough type; not in fine details, but enough to give us a good deal of information in areas like the oceans, where we have very few observations indeed.

Today's satellite, in terms of today's weather—this is today's weather map, just to show you what we might expect, and I hope to verify this in a few moments, when we get the data and have it put together—would go something like this: As you know, the satellite will only go up as far as 34 north, about to this point, but in so doing it will show some cloud systems. It will show the typical stratus off of California, sort of a dull gray cover, low down, as you know, with foreign substances in the air around southern California which keep things a little on the dull gray——

Mr. YATES. You do not mean smog?

Dr. WEXLER. Yes. I didn't want to use that in Dr. Revelle's presence.

Mr. YATES. Dr. Revelle does not have any smog; do you?

Dr. WEXLER. There will be a clear area over the western mountains, and then, as the satellite comes farther east, over Texas, to the north, there will emerge a very solid cloud deck caused by air from the mountains, pushing over this dome of Canadian arctic air coming down from the north.

This gray area is some snow, with clouds, and so this would show up very good. There would be clear weather for the most part in Texas and along the gulf coast, but then coming here to the east we would get to the southern part.

Mr. YATES. What is this?

Dr. WEXLER. This is rain and snow in the Great Lakes area. The satellite does not go quite that far north. It would get the southern part of this developing storm, which is now taking shape here in

the East, and shows a very extensive cloud deck in the Southeast. As far as Chicago is concerned, Dr. Reichelderfer's prediction is exactly correct. It is an improving situation.

Dr. BRONK. How about LaGuardia?

Dr. WEXLER. That is a tougher situation. The coastal storm is taking shape but not too quickly. I hate to stick my neck out as vigorously as I did for Chicago, but I think it would be operational.

ANTARCTIC PROGRAM

The other great impact of the IGY has been in the Antarctic.

Here, for the first time, we have had sort of a meteorological unveiling of the Antarctic, and we found out that the Antarctic is not flat climatologically speaking. Everyone speaks of the Antarctic as cold, snowy, and miserable. It isn't. It has a great range of climate. As a matter of fact, I was quite interested in seeing that the difference in temperature that occurs in wintertime between our "banana belt" station, the Wilkes station, and the Pole, is larger than the difference in temperature between Miami Beach, Fla., and the Canadian Arctic. There is a difference in temperature of something like 74 degrees Fahrenheit, average winter temperatures between here and here, which is greater than—or just about as great as Miami Beach and the Arctic.

Mr. YATES. What would the temperatures be?

Dr. WEXLER. It is pretty cold. The average would be 15 degrees F. plus at Wilkes and minus 60 here.

Mr. YATES. Wilkes would be like Chicago?

Dr. WEXLER. Yes. They have very strong winds. What they lack in low temperature they make up in terrific winds. 100 miles, or 150 miles an hour are by no means rare.

Dr. BRONK. Isn't there a big valley where you don't have winds and also a reasonably high temperature?

Dr. WEXLER. That was once thought to be the case. This whole thing is a high plateau and the winds cascade down.

Dr. BRONK. What is this area that Berkner is advertising as a tourist resort?

Dr. WEXLER. That is over here. I was going to describe its tourist aspects in a little while.

The Antarctic is composed of these two regions, East and West Antarctica. This is where the ice is piled up to great heights, perhaps 14,000 or 15,000 feet, resting on rock a few thousand feet above sea level. Here the elevations are not quite so high, perhaps 7,000 feet. Over the valley, storms have sort of sculptured the shape of Antarctica. The winds and the snow storms accompany all these storms, and have put down snow, ice, and it has been like an enormous sculpture, just shaping this whole big plateau of ice, which has taken thousands of years to do. Theoretically, it could be done in 15,000 years. In so doing the storms become affected themselves. That is, the storms which could cross into here and deposit snow are now blocked by this great bulk of ice, and tend to go along the coast, and in so doing help suck down, you might say, that air, which gives the very strong blizzards at Wilkes, and other coastal stations. The storms have been deflected so that now, instead of going in as they did in prehistoric times, they apparently come into this area and are deflected into the Ross Sea area and come into West Antarctica. This

again is where IGY revealed something interesting. Storms have no difficulty in crossing from here to here and in so doing—from the Ross Sea to the Weddell Sea, and in so doing deposit very heavy amounts of snow at Byrd station.

ICE AGES

All evidence seems to point to the fact that here the Ice Age has reached its maximum and is receding, and here are some of the valleys, the dry valleys that Dr. Berkner talked about which once were covered with ice, but which are now receding because the ice is diminishing, the spillover over the heads of the valleys of ice have diminished so now they are very large, dry valleys, since they are not nourished, and could be, probably, with some experimentation, suitable for human occupation the year around.

The lowest temperature observed in one of these valleys last year was 15 below, not bad at all. There is plenty of water there.

Also, another evidence that the ice is receding is the fact that you see some raised beaches, beach lines, perhaps 75 feet higher above present sea level, which indicates that the land is rebounding, as Dr. Woollard pointed out, as the burden of ice recedes.

Mr. YATES. I think you would do the reader of these hearings a favor, if when you say "here," you would name the place.

Dr. WEXLER. Yes. These would be raised beach levels at Marble Point near the Taylor dry valley, on the east coast of the Ross Sound.

In West Antarctica the ice is building up extremely rapidly and it is estimated that at the present rate of accumulation, about 10,000 years of snow storms would be enough to have built that ice up to 10,000 feet, which seems to be an average thickness here.

What I am trying to get at here is the connection between events that took place here, the depletion of storms that passed when this thing built up and the beginning of the Ice Age in West Antarctica as the Ice Age in East Antarctica is receding. To put the thing in the world context, the ages I speak about fit in very nicely with Northern Hemisphere ages; namely, it is about 10,000 years ago that the melting of ice in North America reached its maximum. As you know, we had, perhaps 30,000 years ago, a rather warm interglacial period in North America, followed by the Ice Age, that locally has been called the Wisconsin Age, which reached its maximum some time around 18,000 years ago, from 18,000 to 20,000 years ago. Most of that ice melted in that time, during which the sea level raised by 220 feet. These years I give you are quite comparable to the times that have occurred here in Antarctica, namely, about 10,000 years ago, apparently, the ice started building up in West Antarctica, at about the time, we think, although we don't have sure evidence on this right now, that the ice reached its maximum in East Antarctica. There seems to be very definite connections between events here governing ice ages in Antarctica and ice ages in the Northern Hemisphere. We still have a potential of another 200 feet rise in sea level, which definitely took place in 8,000 years. If all this ice should melt we would get another 200 feet in sea level.

Well, what I have tried to give you is a connection between meteorology, glaciology, climatic changes, oceans involved, as sort of an example of the interplay that takes place between scientific disciplines brought on by the IGY.

ANTARCTIC STATIONS

In a few moments I would like to mention the plans for the future. As you know, the United States has supported during the IGY seven stations all together: the Ellsworth station on the Weddell Sea, the Byrd station in the middle of Marie Byrd Land, the South Pole station, the famous and historical Little America, the McMurdo station, which is a limited scientific, mostly a logistics base, Cape Hallett station, and the Wilkes station. In addition, we have done a good many traverses as shown by the red, blue, solid, and dashed lines, perhaps 10,000 miles of traverses has been done since the IGY program began 2 years ago in the Antarctic.

FUTURE ANTARCTIC WORK

Our plans for the future are somewhat in fluid stage. We definitely know that the South Pole is being retained, in fact, it is being manned now by scientists. The Byrd station is being maintained. The McMurdo, the Navy logistics base, is being maintained in close cooperation with the New Zealand-Scott station in the neighborhood; the joint station at Hallett is being maintained. Wilkes is being operated by a joint program between Australia and the United States, with the United States furnishing three scientists. At Ellsworth, it is being maintained with a joint program with Argentina, with the United States furnishing one scientist.

Little America has been abandoned temporarily, we hope. Little America is perhaps the most valuable of all scientific stations in Antarctica. It is a station that has shown clearly for the first time in Antarctica a warming trend of perhaps 5° F. since 1912, which fits in with the warming trend that has been noticed elsewhere in the world, particularly in the Arctic. There has also been drilling at Little America which has almost pierced the 850-foot-thick Ross ice shelf and this Ross ice shelf in itself deserves a little bit of mention.

Using the temperatures at Little America, it appears as if the ice has been over Little America over 200 years, perhaps, during a fourth of which the ice has been melted by the ocean current.

There are units here which are unique. Here we have the darkness of the great depths because of the thick coating of ice and snow, but not the pressures. Here we have the separation of the water from the air by the thick ice, meaning you do not have the nutrients coming down from top layers as found in other areas, so you might have a very unique form of marine life, biologists tell me.

INTERNATIONAL PLAN, SCAR

Internationally, there is an organization which has replaced the IGY, SCAR, Special Committee on Antarctic Research, which has had two meetings and will have a third meeting in early March in Canberra, Australia. There are 12 nations members of SCAR, and each of the nations involved in IGY work has kept up its possible IGY Antarctic programs. As a matter of fact, Poland has announced an intention to join in Antarctic work and has taken over a Soviet station at Bunger Oasis, an ice cover discovered by the American naval aviators a decade ago.

Poland will undoubtedly become a member of SCAR because of its activity in Antarctica. Two other nations, Germany and Italy, have talked about participating, so the program in Antarctica is proceeding nearly as vigorously as during the IGY. In fact, there has been no diminution we have been able to find on the part of the Soviets; in fact, an increase in their activities and other nations are coming in.

I think that is about all I have to say on the combined subjects of meteorology, glaciology in the Antarctic. I will be very glad to answer questions.

REDUCING U.S. EFFORT IN ANTARCTICA

Mr. THOMAS. Doctor, what did our friend Dr. Gould mean when he said we were abandoning our activities in the Antarctic? Did you read his telegram?

Dr. WEXLER. Yes, sir. I believe he said we have abandoned Little America and have reduced our activities in Antarctica.

Mr. THOMAS. I believe I understood you to say that perhaps the best station of all, regardless of all the nations' stations, was Little America. Why was it abandoned?

Dr. WEXLER. This station is the most valuable, because of its long history, going back to Amundsen in 1912, and the large number of years of occupation, totaling about eight, which enables you to get a trend. Its abandonment, I think, was probably simply a question of money and manpower.

Mr. THOMAS. Which ones do we keep now?

Dr. WEXLER. We are keeping the South Pole, Byrd, McMurdo, and jointly with New Zealand, Hallett, and we do have cooperative programs at Wilkes with the Australians and at Ellsworth with the Argentines, which nations have taken over custody.

IMPORTANCE OF LITTLE AMERICA

Mr. THOMAS. Anyway, we elected our choice in keeping four or five stations open and you abandoned that one through choice? The choice was measured on the relative importance of that particular station, Little America, with some four or five others we had there?

Dr. WEXLER. I don't know whether the scientific aspects were given as much weight as some other aspeacs.

Mr. THOMAS. Who decided it?

Dr. WATERMAN. There is a difficulty there, as I understand the Navy's part in it. They said the station was in bad condition and had to be renovated in order to be maintained permanently. Furthermore, it is on the ice shelf and in danger of breaking off from the continent.

Mr. THOMAS. Which base do we use as our main supply base now?

Dr. WEXLER. McMurdo Sound.

Dr. WATERMAN. The value of Little America is very great from the scientific standpoint, from the continuity of observations. This was a very awkward position to be in. The Navy maintained it was a most expensive thing to bring it back and ultimately it might be lost.

Mr. THOMAS. How do you mean, it might be lost ultimately.

Dr. WATERMAN. It was a dangerous situation, as I understand it, at the edge of the Ross ice shelf. It might be overwhelmed, as other

ice would subside. That was admitted by everyone but no one knows when that might happen. Is that right?

Dr. WEXLER. Eventually it will drift away, as all ice does, but Mr. Crary, who studied this, thinks it has a minimum life of 10 years, and probably 20 years. I think one of the difficulties facing the Navy was the problem of unloading supplies at the bottom of that big ice barrier. The ships are in rather a hazardous position when they tie up at the edge of the ice which towers above them, and large hunks can fall down.

Mr. THOMAS. How many months of navigation do we have a year at that port?

Dr. WEXLER. About 3 months, from December through February.

OTHER INTERNATIONAL EFFORTS IN THE ANTARCTIC

Mr. YATES. Is there any diminution in the efforts of the U.S.S.R. in its activities?

Dr. WEXLER. No. I believe it is going the other way around. They have not only set up stations in the interior, the deep interior, places where they said they would, but they have now proposed traverses across the continent. One of the traverses will be from one of these interior stations to the South Pole, past our Byrd station, and over to the Bellingshausen coast.

Mr. THOMAS. Is there any diminution in cooperation between the U.S.S.R., American, and the other people there?

Dr. WEXLER. No. Cooperation has been very friendly and fruitful. We have had an exchange of meteorologists in Antarctica for 2 years. It has worked very well.

Mr. BOLAND. Should we increase our efforts in this area instead of cutting them back?

Dr. WEXLER. Well, all I can say——

Mr. BOLAND. I mean increasing them over and above what you plan for the next year.

Dr. WEXLER. All I can say is that the scientific problems here in Antarctica have merely been scratched. I think that we could put more effort into this area from the scientific point of view.

In other words, it would be desirable to find out a lot more things than we have found out so far, but weighing this with other aspects of national policy is something beyond my particular capability.

Mr. THOMAS. Dr. Wexler, did you ever hear the old expression that the most permanent thing on earth was a temporary Government installation?

Dr. WEXLER. Yes.

Mr. THOMAS. I imagine that holds true on ice, too.

Dr. WEXLER. It certainly does. One of the early Little America camps built in 1939 has been completely engulfed in ice but still people can get to it by going down a ladder.

I should say now that Dr. Berkner has come in, it reminds me of the fact that he, Mr. Shapley, myself, Dr. J. Tuzo Wilson, of Canada, president of the International Union of Geophysics, and a few other project leaders, spent the month of November in Antarctica for the purpose of assessing the IGY results and making plans for the future.

Mr. JONAS. May I ask a question, Mr. Chairman?

Mr. THOMAS. Surely.

Mr. JONAS. As I look at the map, I am struck by the fact that the only stations in the interior are Russian stations.

Dr. WEXLER. We have two over here.

Mr. JONAS. I mean in the eastern area.

Dr. WEXLER. That is correct.

Mr. JONAS. Have we deliberately refrained from establishing stations in that great land mass to the east?

Dr. WEXLER. We do have a coastal station.

Mr. JONAS. I am talking about the interior.

Dr. WEXLER. We felt our concentration in this area fitted in with our previous work in this area beginning with Admiral Byrd's expedition in 1928. This is a very important stretch of territory.

Mr. JONAS. We deliberately elected then to take the western side and concentrate there?

Dr. WEXLER. Yes, with the exception of the Wilkes coastal station.

Mr. JONAS. We have never expanded Wilkes or moved out from it?

Dr. WEXLER. We did. We set up an interior station perhaps 60 miles in on the island at Wilkes.

Mr. JONAS. You do not think we would accomplish anything worth while by establishing stations between Wilkes and the South Pole?

Dr. WEXLER. Well, the south magnetic pole was occupied by the French, and they have abandoned it after the IGY. The Soviets have the south geomagnetic pole at Vostok, which will be maintained.

Mr. JONAS. It seems to me the only people who are exploring that section of the land mass are the Russians. I am just wondering whether we are not abdicating the whole area and turning it over to them and we might some day wake up and regret having done so.

Dr. WEXLER. You will notice that heavy blue line going westward out of McMurdo Sound. Crary and his group made a traverse in this area in the past few months and has returned now to McMurdo. We would like to see our capability increase so we could continue such traverses not only from McMurdo but from the South Pole into this area, not setting up stations, but getting out there and taking scientific observations.

Mr. YATES. Dr. Wexler, you indicated that the eastern part of Antarctica was warming up in contrast to the western part. There was more shelter.

Dr. WEXLER. That the ice was receding.

Mr. YATES. The ice was receding. I assume, therefore, it is warming?

Dr. WEXLER. Not necessarily.

Mr. YATES. Can people live where those Russian posts are located for any length of time?

Dr. WEXLER. Only if they take the utmost precautions. They have to bring in food and heated clothing.

Mr. THOMAS. What is the maximum period, 90 days to 4 months?

Dr. WEXLER. No. The Russians have stayed the year around. This is the station where they observed the temperature of 125° below zero.

In so doing the men have to use tubes to breath from and the tubes go under the heated parkas and warm up the air before it goes into their lungs.

Mr. YATES. They lived there a year?

Dr. WEXLER. Yes.

Mr. YATES. What kind of shelter do they have?

Dr. WEXLER. They bring shelters in by sleds and wherever they stop, that is their camp. Then they pushed on the next season until they got to these spots.

Mr. THOMAS. Dr. Berkner, do you want to add anything, or do you want to come in later? What is your pleasure?

Dr. BERKNER. I might only repeat what Dr. Wexler has already said, that the IGY has shown that Antarctica is a continent in a true sense and not just an icy mass; that it ranges from a relatively warm climate on some parts of the coast, very habitable areas to very forbidding areas in the interior.

Mr. THOMAS. What do you mean, a relatively warm temperature?

Dr. BERKNER. Dr. Wexler probably wouldn't be willing to say this; I will stick my neck out. If you go to Taylor dry valley, the guess is the temperatures probably run from 70 above to 30 below, which is probably a better climate than many American cities and it is an area of great rivers, lakes, and I suspect the hills get green in the summertime with reindeer moss, et cetera.

Mr. THOMAS. Is that the resort area that Dr. Berkner was going to open up?

Dr. BERKNER. It is not going to open up in the sense this will ever become a farming community, but after all, Antarctica does have a considerable strategic value to us in other areas.

Mr. THOMAS. All right, Dr. Kaplan.

STATEMENT OF DR. FRANCIS W. REICHELDERFER CONCERNING METEOROLOGY

Dr. KAPLAN. Our next speaker is Dr. Reichelderfer, who will talk about the overall aspects of meteorology, with emphasis on the program of the U.S. Weather Bureau. I think you all know Dr. Reichelderfer.

Mr. THOMAS. Dr. Reichelderfer is also a member of the Committee, a distinguished and outstanding agency head. We are delighted to have you with us, Doctor.

Give us a good talk like you always do.

Dr. REICHELDERFER. Thank you, Mr. Chairman.

As Dr. Kaplan stated, I am not going to talk about the substance or results of the IGY in depth, but I would like to comment on some of the interesting relationships of meteorology in general and make some remarks about the relationship to the general weather services programs of the Weather Bureau. This latter is a subject in which almost everyone is interested, because of the daily interest of the public in weather services and in storm warnings.

I would be glad to present this offhand without notes, but that would be much longer. I have boiled down my outline of remarks this morning and I have just about what I want to say in some notes, and if you have no objection, I will stick to the notes.

Mr. THOMAS. Anyway you want to present it suits us fine.

Dr. REICHELDERFER. This will be brief, and I will be sure I cover the points I think are important.

Mr. Chairman and members of the committee, among the popular questions often asked of meteorologists since July 1, 1958, when the International Geophysical Year began is "What is the practical value of IGY data in the forecasting of weather?" (Not infrequently the Weather Bureau is asked pointedly, "Will you soon be able to predict the weather a year in advance?" and "Will you be able to 'control' the weather?") Probably most people with a real interest in science now know that this 18-month period of data gathering is just the beginning. The compiling and processing of data and the painstaking research aimed at fuller knowledge and understanding of weather phenomena and their interrelationships and interminable changes will go on for many years. But in meteorology there have already been large "dividends" from the generous appropriations invested in the IGY. These benefits have not yet accrued to weather forecasting in the sense usually of interest to the public. So far they have gone largely to other aspects of weather science, that is, other aspects of meteorological in general.

METEOROLOGICAL REQUIREMENTS

For example, one of the serious problems in supporting services for operations of civil and military jet aircraft at high altitudes has been the deficiencies in upper air soundings to heights of 50,000 feet or more and deficiencies in reports of the wind speeds and boundaries of so-called jet streams aloft and their frequent changes. The expanded radiosonde program of the IGY has provided much additional data at high altitudes and this information has been very valuable for jet aircraft operations almost from the beginning of IGY.

There is much yet to be done. For example, the military services are insistent on four upper air soundings instead of two as we have at the present time because of rapid changes in the jet stream and other upper wind conditions.

Another result that began almost immediately and will continue indefinitely is the growing awareness throughout the world of the necessity for augmenting upper air sounding networks.

Many of the smaller nations that never before operated upper air stations now have these facilities through international cooperation and are making one or two upper air soundings every day. This recognition in many remote lands of the importance and the economic applications of meteorology is being extended to other kinds of weather information and services in addition to upper air reports.

METEOROLOGICAL SATELLITES

For the future perhaps the most significant results from the IGY will be the impetus and support this international program has given to development of artificial earth satellites equipped to carry meteorological telemetering devices. The future possibilities of this source of atmospheric observations are too varied and far-reaching to be discussed in detail here but many meteorologists are confident that they will be in a very real sense the begininng of a new era in meteorology

as regards fundamental knowledge and new techniques they will bring to some phases of weather forecasting. The meteorological satellite successfully launched yesterday by a Vanguard rocket is a preliminary test model—a rather simple, elementary device compared with the much improved designs that will eventually be placed in orbit to transmit to earth's main meteorological centers hourly measurements of the energy received from the sun and percent retained as some form of heat by the surface soil, the oceans, the clouds, etc., where it serves as the driving power for the atmospheric engine (the general circulation) which produces the changes in weather and climate. Future satellites will give hourly composite pictures of the cloud systems over the globe and will reveal formation of hurricanes and perhaps other atmospheric disturbances that give birth to severe squalls and destructive tornadoes. The promise of continuous tracking of the "eye" of a hurricane and the more accurate observations of changes in its course and delineation of its boundaries and limits of destruction is in itself likely to lead to manyfold repayment of the total investment in the IGY. Although meteorological satellites would no doubt have come eventually even without IGY, the speedup incident to this program is likely to yield much earlier protection of life and property during severe storms. The reduction in property losses alone as result of precautions made on basis of accurate forecasts amounts to millions of dollars. Future earth satellites will also give reports on other features and elements of the atmosphere essential to an understanding of weather.

PAST INTERNATIONAL COOPERATION

It may be surprising to some that IGY is not an entirely new program in meteorology. Without detracting in the slightest from the new concepts and great accomplishments represented in the IGY it may be stated quite factually that "international meteorological years" began some 75 years ago with the daily exchange of weather reports by telegraph and cable among many countries and this daily exchange has continued ever since, greatly augmented since 1910 by weather reports via radio communications. Every day the Weather Bureau receives by telecommunications thousands of surface and upper air reports from North America, Europe and Asia including the Iron Curtain countries and from other parts of the world. Even so, the present "sampling" of the atmosphere for purposes of weather analysis and forecasting is less than 5 percent and perhaps less than 1 percent the comprehensive coverage of atmospheric conditions that will be necessary to satisfy the "requirements" of the increasingly complex operations and techniques of aeronautics, agriculture and the many other human activities in which plans and operations are vitally influenced by weather and climate. Thus, in perspective, it appears that the accelerated and expanded programs of the IGY have been but the first step toward more comprehensive networks for geophysical observations which man will find necessary as a permanent daily routine.

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U.S. WEATHER BUREAU RESPONSIBILITIES

The relationships of the IGY programs just past and the future IGC programs to the public weather service responsibilities of the Weather Bureau must now be rather obvious. In recent years the term "requirement" has come into common use in government, first in military circles and now in civil agencies, to designate a proposal or plan which appears (to its proponents, at least) to be necessary in the discharge of its recognized responsibilities. The Weather Bureau has an inexhaustible "backlog" of unfilled "requirements" for which the augmented meteorological observations of the IGY have given a degree of amelioration. The magnitude of the Bureau's responsibilities in this connection is evidenced by the following brief quotation from Public Law No. 657, 80th Congress (S. 2456):

> *Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,* That the Chief of the Weather Bureau is authorized and directed to study fully and thoroughly the internal structure of thunderstorms, hurricanes, cyclones, and other severe atmospheric disturbances, particularly the degree of turbulence within such storms and the development, maintenance, and magnitude of updrafts and downdrafts with a view to establishing methods by which the characteristics of particular thunderstorms may be forecast and methods by which the characteristics of such storms may be determined by visual observation from outside of the immediate thunderstorm area. Such study shall be concluded at the earliest practicable date and a final report submitted to Congress. The Chief of the Weather Bureau shall make interim reports to Congress at least annually during the course of the study.

The point I wanted to bring out is the Congress at that time recognized the great importance and the urgency of meteorological research and directed the Weather Bureau to investigate all manner of disturbances, even mentioning updrafts and downdrafts and turbulence. We are a very long way from that goal in the overall general circulation sense.

Translated into practical terms in relation to recent weather events, the following may be cited: This week the flood-control engineers along the Wabash River in Indiana had the requirement for an extended weather forecast so they could decide wisely whether to dynamite the ice jam possibly endangering bridge structures downstream for long distances, or await natural melting by warmer weather with less risk of bridge damage. Another recent example, the frequent blizzards and icing conditions during the winter in the Midwest have brought highway accidents and deaths that could have been avoided through studies of meso-meteorology and more detailed local forecasts based thereon. Still another example, last week a tornado struck St. Louis shortly after 2 a.m., the funnel dropping down suddenly near the city with no possibility of detection by present techniques early enough to flash warning to residents to seek shelter in their basements. A score of lives were lost. Before long, improved designs of radar will detect such disturbances more promptly and better meteorological facilities will provide warnings in time to avoid loss of life. The list of such requirements is endless, because weather affects man and his plans and activities in innumerable ways. Future studies of IGY data will aid in attaining better understanding of the nature of these problems and the best practical means for meeting the requirements involved.

With all of the miracles that have been brought to reality in science during recent years, it was inevitable that there would be here and there an outbreak or two of fabulous nonsense about what man is on the verge of accomplishing. In particular, this has been the case with some of the reported claims pertaining to weather control and rainmaking. Certainly there are practical possibilities in these fields, but it requires very much more research—basic research—to discover what these possibilities really are. Now there seems to be no doubt that the practical possibilities are much more limited, either by problems of the magnitude of the task or by those inescapable consequences which constitute a cure that is worse than the disease, or by both of these considerations. Research and development in weather modification should proceed as rapidly as resources and sound research plans are available, and here again the IGY has been a first step toward getting the more comprehensive meteorological data required for full knowledge and understanding of the subject.

Mr. THOMAS. It is a very nice statement, Doctor. Thank you very much.

NUCLEAR TESTS AND WEATHER

Mr. YATES. Popular belief has it there is a relationship between the nuclear explosions and the formation of weather. Do you believe that?

Dr. REICHELDERFER. This is a thing that cannot be positively proven one way or another, but there have been very extensive studies, some sponsored by the AEC, some by other agencies. The Weather Bureau is in the middle of it.

There is no reason to believe that explosions up to the present time have had any permanent effect. There are some local effects that are transitory, a few hours or so, but no evidence of any permanent effects.

An authority no less than John Von Neuman and I believe Dr. Teller, they have said the same thing and others not as well known, that if debris and dust particles were thrown into the air day after day or week after week for a long period, this undoubtedly would change the radiation balance and heat balance of the atmosphere and would induce some long-term, large-scale change, but nothing up to the present time.

STATEMENT OF DR. WALTER ORR ROBERTS CONCERNING SOLAR ACTIVITY AND COSMIC RAYS

Mr. THOMAS. That is very fine. What is next, Dr. Kaplan?

Dr. KAPLAN. We now move to another set of disciplines, Mr. Chairman, having to do with the upper atmosphere and space. To speak first on sun and earth relationships we have Dr. Walter Orr Roberts, who is Chairman of the NAS USNC–IGY Technical Panel on Solar Activity and director of the high altitude observatory, University of Colorado.

Mr. THOMAS. Welcome aboard. Make us a good talk. I know you will.

(Dr. Roberts' prepared statement follows:)

I. IGY Programs in Solar Activity and Cosmic Rays

It is a privilege for me to examine with you the findings of the IGY observational program in fields of solar activity and cosmic rays. We are on the threshold of entirely new conceptions of the influence of the sun on the space environs of the earth. We have come to this point through, in no small part, the remarkable interdisciplinary program of research of the IGY. Scientists everywhere now look upon the intensive measurements made during the IGY as one of their principal resources in the development of scientific findings about our planet. It will be many months, in fact many years, before the IGY resources of data are fully evaluated and exploited. But it is of interest, even at this early stage, to observe some of the discoveries already achieved. I shall therefore try to cover some of the highlights of the contributions of the IGY to our rapidly emerging knowledge about effects on the earth produced by two astronomical phenomena, the sun and the cosmic rays.

SOLAR ACTIVITY

The earth, some 90 million miles from the sun, sweeps unceasingly through the ever-changing medium of space. It speeds at over 18 miles per second in its nearly circular orbit about the sun, while the sun and the planetary system as a whole move through interstellar space with a speed of about 12 miles per second in a direction roughly toward the bright star Vega. The medium we traverse in this space flight strongly affects the earth and its atmosphere. The medium, in turn, is principally controlled by the sun. As the sun's emissions change, the physical properties of the tenuous gases in space near the earth change significantly.

Every 11 years or so the sun passes through a peak of activity, with lows in between. However, the highs and lows are somewhat irregular in timing, and individual days or weeks may display great peaks or valleys of activity compared to longer term averages, particularly in the 4 to 5 years that follow maximums of activity. With these changes go a variety of effects in radio communications, earth magnetism, cosmic rays, auroras, and probably also in weather and climate, though these last two must today be called speculative.

During the IGY period the sun, in rare cooperation with the long-term prognosticators who planned the IGY dates, reached the highest level of disturbance ever recorded. On Christmas Day in 1957, for example, the number of dark sunspots visible on the solar face reached what is probably the highest value since Galileo made the first telescopic drawings of sunspots in 1612. Associated with the 1957–58 rise of sunspot activity was a great rise in the number of solar flares, those spectacular hydrogen cloud brightenings in the sun that rise explosively to peak intensity in a matter of minutes and subside to normal over matters of a few hours. From flares, which often cover hundreds of millions of square miles of the sun's surface, come powerful bursts of X-ray and ultraviolet light and intense streams of electrically charged atomic particles. When the particle streams impinge on the earth's atmosphere they sometimes produce dramatic displays of the aurora, and severe upsets of radio communications and earth magnetism.

To learn how and why these solar emissions so powerfully affect the earth has been a central objective of the IGY program. Scientists in many fields of geophysics have made all-out efforts during the IGY to obtain complete measurements of solar flares, the solar corona, sunspots, and other solar events for comparison with extensive simultaneous observations of the aurora, geomagnetism, ionospheric storms, cosmic rays, weather conditions and many other geophysical phenomena. With the help of such data we are already beginning to gain new insights into the mysteries of our earthly environment.

The IGY solar program can be divided into two functional goals: (1) The solar patrols designed to provide as complete as possible a history of the quantitative details of varying solar activity for correlation with discoveries in geophysical disciplines, and for warnings of expected geophysical effects, and (2) the solar observatory research programs designed principally for discovery of basic facts of solar physics.

Patrol programs

More than 100 patrols—visual, optical, photographic, photometric, and radio—kept the sun under constant watch at every minute through the IGY period. This unprecedented watch on the sun yielded ample returns. For the first time in history we can be certain that for long periods of time no solar flares have escaped detection. From throughout the world this solar information was channeled by solar observatories to the IGY World Warning Agency in the United States. There daily analyses were made of the likelihood of further solar outbreaks and of sun-induced earth effects. Between June 28, 1957, and December 31, 1958, these analyses led to the calling of 40 alerts—messages radioed to participating IGY stations throughout the world, calling attention to the heightened probability of unusual geophysical activity and alerting these stations to stand by for the possible declaration of a special world interval. There were 21 special world intervals between June 28, 1957, and December 31, 1958, and their declaration permitted scientists everywhere to intensify measurements in order to catch all possible details of major atmospheric disturbances that often follow in the wake of major solar outbreaks.

The IGY period, as I have mentioned, witnessed the greatest level of solar activity in modern history: the Zurich Observatory, international clearinghouse for sunspot statistics, reported that 1957 had the highest yearly mean in relative sunspot numbers since 1778. The overall level of activity during 1958 seems to have been only a small amount lower. From the standpoint, therefore, of choosing the best time for the IGY, the success could not have been more complete.

Over 30 observatories, 7 of which were in the United States, took photographs of the sun every 3 minutes or more often, with special filters designed to isolate the light of the hydrogen and calcium gases in which flares are most active. These photographs, in effect a time-lapse motion picture study of the sun's face, provide, together with other related observations, the most detailed record of the sun's activity in history.

Observatory programs

In addition, several new solar measuring instruments were developed for the IGY. One such new instrument was the K-coronameter. This is a device for measuring and recording the brightness of light scattered by free electrons in the sun's tenuous atmosphere—the so-called electron corona. Although the electron corona is visible to the naked eye during a solar eclipse, astronomers are unable to photograph it at other times because the brilliant light from the face of the sun completely overpowers the comparatively weak rays from the corona. The K-coronameter, in operation at the High Altitude Observatory's Climax station on the Continental Divide, records the intensity of coronal light by electronic means. The electron corona is probably composed, at least in part, of the actual aurora-producing solar particles in the beginning of their 2,000-mile-per-second flight from sun to earth. Thus we hope to discover how and why they are accelerated to these enormous velocities near the sun. These same particle streams seem also to be the source, at least on occasion, of powerful bursts of radio noise from the sun. But the theories of the generation of this noise are still uncertain.

Some regions of the sun reach temperatures of 7 million degrees (Fahrenheit) or more, although the underlying solar surface is about 10,000° F. These hot regions of the corona were also extensively studied at some eight solar observatories, two of which are in the United States. These stations used the Lyot-type coronograph invented in France in 1930, and extensively developed at Climax and Sacramento Peak in the United States. The possible consequences of this hot corona for the space environment of earth are spectacular. Professor S. Chapman, president of the International Special Committee for the IGY, has proposed a new theory of the interplanetary medium based on the conduction of heat from this corona into space. In Chapman's new theory the earth lies well within the clouds of gas of the solar atmospheric corona, and in a tenuous gas of over 350,000° F. This gas constantly conducts heat into the earth's upper atmosphere, in Chapman's view, where it affects the ionosphere, particularly in polar latitudes. The Chapman corona extends far beyond earth, indeed beyond the orbit of the farthest planet, Pluto, before it declines to the temperature and density characteristic of the space between the stars. The new theory, which still has many critics, and still leaves many problems unsolved, is of great importance to the coming generation of astronauts.

During the IGY, the High Altitude Observatory has observed the spectrum of light from hydrogen gas in a large number of flares. These observations have

enabled us to measure the variations occurring in about 50 small solar flares. A pilot study, which is now completed, has yielded important clues to the structure of flares. Specifically it has studied the opacity of the hydrogen gas in the flares. If the results of this study are confirmed when the analysis is extended to other flares, they will be of the highest importance in deducing how the heat of a solar flare is generated and transmitted to the solar corona, which generally grows brighter and more extensive after a series of flare outbreaks. It may also yield clues as to how X-rays and particle ejections develop in the sun. Such information is essential if we are to understand sun-induced radio fadeouts on earth.

Intensive analysis of spectra pictures from a single flare of September 18, 1957, has been undertaken by the Sacramento Peak Observatory. The flare was photographed with a powerful new Universal spectrograph in light running through most of the visible wavelength range. It is probably the widest range flare spectrum photograph yet obtained in the Western World, and perhaps in the entire world. Analysis of this outstanding set of spectra has given us new information about the great variety of temperatures and pressures within the flare disturbance, but it will probably be some years yet until we can adequately understand where a flare gets its energy and just how this energy is dissipated. In particular, an intensive search is now being made to see whether the element deuterium is present in flares, as was suggested by Russian workers. If it is, then there is a possibility that the flare's energy is derived by atomic fusion, or that fusion processes go on as a byproduct of the flares. Such a confirmation would be of widest theoretical importance.

Measurements of the sun's surface magnetic fields are continuing at Mount Wilson Observatory with most surprising results. Observations begun there in 1948 have suggested that the sun has a general magnetic field rather similar to that of the earth, and of about the same strength, with quite well defined north and south poles. Mysteriously, however, during 1958 the polarity of one of the poles apparently reversed and the other one weakened. It is as as though the south magnetic pole of the earth suddenly began to attract the end of the compass needle that previously had pointed toward the north magnetic pole and the north magnetic pole, in turn, also attracted the same pole as before but more weakly. These observations are most startling and no one has as yet advanced a theory about their cause. Observations will continue and perhaps from them may someday come a far deeper understanding of solar magnetism.

Solar eclipse of October 12, 1958

On October 12, 1958, a total eclipse of the sun occurred in a path across the South Pacific. Despite many advances in the design and development of solar telescopes and other solar observing equipment, a total solar eclipse still gives the astronomer his best opportunity to observe the very inner regions of the sun's corona and chromosphere. The chromosphere is the narrow region that lies between the solar surface and the corona, and in this shallow layer of the atmosphere the temperature increases drastically from 10,000° F. to the multi-million degree range of the corona. The occurrence of an eclipse during the IGY and at a time of maximum solar activity was especially opportune for solar studies, and this led the Air Force Cambridge Research Center to initiate planning for an expedition to the eclipse. Ultimately a broad observational program was planned, and a special expedition organized around many participating groups. The U.S. Navy supplied a ship and logistic support to carry the participating scientists to Puka-Puka (also known as Danger Island) an atoll in the Cook Island group administered by New Zealand.

Scientists and engineers from the Naval Research Laboratory remained on ship to conduct rocket experiments during the eclipse. On shore, scientists from Sacramento Peak Observatory, the High Altitude Observatory, the Central Radio Propagation Laboratory of the National Bureau of Standards, the University of Wisconsin, the California Academy of Sciences and the Navy Radiological Defense Laboratory prepared to conduct optical and radio observations during the eclipse.

Existing weather records indicated about a 50 percent chance that clouds might obscure the sun during the period of total eclipse, but in view of the great potential returns, these odds were reasonable ones, moreover, clouds would impede only the optical experiments. As it turned out a thunderstorm covered the island during the crucial period, much to the distress of the optical observers.

The four optical experiments that stood idle under the cloud-filled sky were intended to make measurements of the green and yellow emission lines of the sun's corona, to detect the polarization of the white light corona, to observe

quantitatively the "shadow bands" thought to be produced by variations in the earth's atmosphere and finally, to photograph rapid-sequence spectra of the lowest layer of the sun's atmosphere.

Partially successful, the fifth experiment was an attempt to observe light emitted by oxygen atoms in the earth's atmosphere during the daytime. Its purpose was to test observationally the intensity of this "dayglow" and thus check the values determined by theoretical studies. Fortunately, a single hole in the overcast was detected at eclipse time and observations were made with a telescope pointed directly at this hole. The intensity observed was substantially less than the predicted value, although further analysis is needed to determine quantitatively the effect of the clouds on the measurements.

Rocket experiments were designed by the Naval Research Laboratory to measure X-ray and ultraviolet emissions from those portions of the sun such as sunspot regions, which were covered and uncovered during various stages of the eclipse. Five rockets were sent aloft during the eclipse. It was discovered that the hydrogen radiation appeared to follow very closely the uneclipsed area of the solar face. This radiation almost disappeared within a few seconds after totality. In strong contrast, however, the flux of X-rays from the sun persisted throughout totality. Measurements showed a great increase of X-ray emission about the rim of the sun. Thus the sun appeared to be ringed by a bright X-ray halo.

Unexpectedly valuable data were received when a last rocket was fired on the morning of the day following the eclipse. It happened that a large solar flare was in progress during the firing. The rocket performed exceptionally well and the data showed that the amount of X-rays was strongly enhanced during the flare, while the most important hydrogen emission showed no significant variation. This result is of great importance since there has long been speculation as to which of these two radiations might be responsible for disturbances in the ionosphere during solar flares.

Another experiment which succeeded despite the clouds was conducted by the Sacramento Peak Observatory and High Altitude Observatory groups with equipment built during the IGY to detect solar flares indirectly by observing their effects on the terrestrial ionosphere. Radiation from a flare increases the number of free electrons in the ionosphere and thereby changes its ability to transmit radio waves, both those coming into the earth from stars far out in space and those generated close to the earth by thunderstorms. Thus changes in ionospheric transmission of these two types of radio noise during a flare provide an indirect measure of the amount of radiation coming to the earth from the flare.

Three of these indirect observational instruments were built for the worldwide flare detection network. A fourth was taken to the Danger Islands for use during the eclipse and later permanently installed at the University of Hawaii. The equipment was operated nearly continuously at the island from September 15 through October 17. The records obtained during the eclipse itself were of good quality. Analyses suggest the strong hydrogen radiation is not the principal ionizing agent in the lower region of the ionosphere, as we previously believed. Thus it is possible that X-rays are the principal ionizing agent, although further studies must be conducted, before this question can be firmly answered.

II. Cosmic Rays

Cosmic rays are electrically charged particles travelling with speeds approaching the velocity of light. They apparently come from within our galaxy and bombard the earth from all directions. Nearly half of the energy of the universe appears to be contained in cosmic rays. The period of maximum of solar activity during the IGY was especially fortunate for their investigation, since some of the discoveries made in the IGY cosmic ray program would not have been revealed during a period of sunspot minimum. The results from the IGY programs for solar activity, auroras, geomagnetism, ionosphere and rocketry all have produced data which will aid in the interpretation of cosmic ray results.

Changes of cosmic radiation with time

Cosmic radiaiton fluctuates appreciably with time, particularly for the low energy component. The sun, on occasion, may either increase or decrease the low energy cosmic radiation at earth. The most spectacular changes, of which only five instances exist, are increases produced by solar flares. The greatest on record occurred before the IGY on February 23, 1956, and produced at Climax, for example, a 40 times increase in cosmic ray neutron counters operated

for the University of Chicago. The increase was so that the observer in charge thought, at first, that the instrument had broken down. The IGY program had led to pre-IGY installation of several counters to serve as prototypes of the IGY network. Thus the IGY indirectly improved the coverage of this event. The event, in turn, stimulated great interest in time variations and led to an outstandingly fine network of IGY stations for cosmic ray detection at all latitudes.

As has been reported at an earlier visit with your committee, IGY scientists, using a variety of techniques, have found that the number and kinds of cosmic ray particles arriving at the earth have changed drastically between the last minimum of solar activity (1954) and the solar maximum during the IGY. During the past two 11-year solar cycles the department of terrestrial magnetism of the Carnegie Institution of Washington has operated ionization chambers which record the intensity of the higher energy component of cosmic rays. From these data a worldwide 11-year cosmic ray variation was found in which this component increased at sunspot minimum and decreased at sunspot maximum.

Another interesting observation was that during some magnetic storms this high energy cosmic ray component sometimes decreased within a few hours, but then took days to recover from normal. During the IGY there were more such cosmic ray decreases observed than in any comparable period in the past 20 years.

One may also compare the variation of the high energy component of cosmic rays with measurements of the lower energy component made with neutron monitors in the years preceding and during the IGY. Comparison of data between 1954 and 1958 shows that the variation of this low energy component is much larger than for the high energy component, showing that the sun's effect is strongest on the lower energy cosmic ray particles. We speculate that clouds of electrified particles ejected from the sun, and presumably those same clouds that produce auroras, pass far out into the solar system and there shield the earth from incoming cosmic rays. The number and potency of these clouds certainly increase during sunspot maxima, and thus the clouds, by methods that are yet obscure, may absorb or deflect a larger number of cosmic rays, presumably screening out more low energy particles than high energy ones.

Balloon flights made between 1953 and 1958 have shown that the number of high energy cosmic ray particles coming from outer space was about half as great in 1958, near sunspot maximum, as it was in 1954 near sunspot minimum. Balloon flights near the north magnetic pole showed that low energy particles, which were present in 1954, were completely missing in 1957.

In the earth's magnetic field, the paths of the incoming charged cosmic ray particles are curved; the particle trajectories are bent more severely when the energy of the particles is low, and when the path comes at larger angles to the earth's magnetic lines of force. Thus a cosmic ray particle striking near the earth's equator must have very great energy to avoid being bent so much as to miss the earth entirely. To reach the equator a cosmic ray particle consisting of a proton (a hydrogen nucleus and one of the most common of cosmic ray particles) must have a minimum energy of about 15 billion electron volts, whereas protons with perhaps a tenth or even a hundredth of this energy can reach the vicinity of the poles where they are detected from balloons flying above the denser lower atmosphere in which they would be absorbed.

The phenomena of magnetic storms and auroras seem to support the hypothesis that the sun ejects large clouds of highly conducting gas which carry with them magnetic fields. On the other hand, the exciting discovery of the Van Allen radiation belts, perhaps the most spectacular discovery of the IGY, discussed elsewhere in this testimony, may throw quite a new light on this theory and may lead to a new and quite different hypothesis.

IGY balloons have been flown to determine whether there is any change in the relative numbers of protons and alpha particles (helium nuclei) in the cosmic ray flux. Interestingly enough, balloon flights during 1957 and 1958 indicate that generally the mechanisms responsible for variations in cosmic ray intensity affect both alpha particles and protons in the same manner; so the ratio of these two cosmic ray components remains constant. However, it seems likely that in the period following great cosmic ray decreases which accompany geomagnetic disturbances, the alpha particle flux may behave independently of the proton flux. This is important information since it may be used to infer the nature of the mechanism in interplanetary space which is responsible for the decreases.

X-rays at the top of the atmosphere

At an earlier discussion with the committee, it was noted that one of the most interesting new discoveries arising from the IGY program was the discovery of X-rays in the high atmosphere detected by cosmic ray balloon techniques. In one balloon program carried out in Minnesota, some 75 balloons have been launched since the beginning of the IGY for the observation of both cosmic ray intensity and X-ray radiation. The balloons rose to about 100,000 feet and remained at this altitude for about 1 day. The strong bursts of X-rays appeared always in connection with aurorae that showed rayed structure, not with the other auroral forms. At the same time large changes in the earth's magnetic field were recorded at several observatories. An IGY balloon flight, conducted earlier under joint United States-Canadian auspices, revealed X-rays during geomagnetic disturbances, probably of the same character as those in the Minnesota experiments. The X-rays are probably produced by electrons striking the top of the atmosphere, and the electrons, in turn, probably arrive at the earth in clouds ejected by the sun. As mentioned above, however, the existence of the Van Allen radiation belts may drastically change our thinking on these questions.

Gamma radiation from the sun

A new phenomenon was observed during the solar flare of March 20, 1958, when a balloon was flown by the U.S. investigators in Cuba. Ionospheric, magnetic, and earth current disturbances and solar radio emissions accompanied the occurrence of the flare. The phenomenon observed was a burst of so-called gamma radiation which is electromagnetic radiation of shorter wavelengths than X-rays. It is believed that the observations can be accounted for by radiations coming from electrons in the sun's atmosphere which were accelerated during the growth of the solar flare. In this theory the solar radio waves came from emission by these electrons as they spiralled in the intense magnetic fields associated with the sunspot group. The electrons finally were stopped in the solar atmosphere, and some of their energy was radiated away as the gamma rays which we observed at the earth. The theory and observations need extensive future confirmation.

Low-energy protons at the top of the atmosphere

Finally, unusual balloon observations taken in Churchill, Canada, on August 22, 1958, demonstrated the presence of ionizing radiation which appeared in association with great increases in solar radio emission following a solar flare. No auroras were visible at the time and there was little if any magnetic disturbance present. Furthermore, the radiation detected was not X-rays, as previously observed, nor gamma rays from electrons. Rather the measurements corresponded to a stream of protons; once before in 1957 protons had been observed at Churchill during a period of high solar activity but no further confirmation was obtained until the occurrence of the more recent event.

It may be that these protons come directly from the sun. Increased ionospheric absorption of cosmic radio noise was observed in the Arctic following a large solar flare on July 29, 1958, and this absorption has also been shown to be consistent with the effect of protons impinging upon the ionosphere. The evidence from these events suggests that a stream of protons may occasionally arrive in the terrestrial atmosphere in association with flares, even though the stream is not observed at the ground. Only further observations by instrumentation flown above the screening influence of the earth's lower atmosphere will settle the question.

The future

The discovery of the flux of protons present at the top of the atmosphere following solar flares is a good example of the way in which analytical interpretation of observational data proceeds concurrently with the collection of the data. Discovery of the protons and their effects was made during the summer of 1958 and was rapidly published before the year was over. The discovery has, however, only raised new questions which will require much additional experimentation before the full story of the proton stream production and behavior can be deduced with certainty. Other examples of problems newly raised can be readily found from a rapid review of the cosmic ray and solar activity program discussions given above. The USNC–IGY panel on cosmic rays has summarized the important areas of future cosmic ray observational research as follows:

"The Panel is unanimously agreed that a high latitude, high altitude long duration balloon program is of the greatest importance, especially for the fre-

quent investigation of the properties of the low energy cutoff as the solar cycle proceeds. As the solar cycle minimum is approached such measurements should be taken at high latitudes.

"The Panel feels it important to study the detailed character of radiation coming from the ensuing solar flares on top of and outside the atmosphere.

"The Panel recommends that the cosmic ray monitoring should be carried out wherever possible using neutron instruments or ionization chambers. The latter provide data of much greater importance than those from meson telescopes especially since these data have been taken for many years in the past. Observations should continue all the way down to solar minimum. Meson telescopes should be continued where already in operation at locations which fill gaps in chains of the other principal cosmic ray instruments."

The Panel on cosmic rays has also recommended that, in view of the intimate association of cosmic ray intensity with the electrodynamics of the solar system and the solar cycle, the observational programs for cosmic rays and solar activity should continue to be maintained at the same level as during the IGY, at least until the solar minimum is reached. With the background of data already gathered in the solar observational program, one can state that future investigations of the solar atmosphere that show great promise and should be vigorously pursued are:

(1) Studies of the temperature and density structure of solar flares and their associated material ejections, with a view to specification of the radiation output in X-rays and ultra-violet light and the heating influence on the corona; for this, additional high-resolution spectroscopic observations with numerous wavelengths are needed, coupled with theoretical studies;

(2) Studies of the magnetic field structure of active solar regions, with observations and theoretical interpretations of the movement of high-speed clouds of solar gases, above the solar surface, their sudden changes of brightness, their radio emission, and the relation of the gas clouds to the multi-million-degree corona; this study should be coupled with all possible efforts to extend optical and radio observations to greater heights in the solar atmosphere;

(3) Successful completion of the optical eclipse observations described above, at a future solar eclipse, such as that in October 1959;

(4) Cross-disciplinary studies of solar influences on aurora and earth-magnetism, including observational studies of point-to-point variations of the earth's magnetic field as evidences of electrical currents in the lower ionosphere and in the earth's crust;

(5) An intensified effort to develop indices of solar activity that describe the sun's emission not in terms of the observed features of sunspots, flares, corona, etc., but in terms of physically significant details of the radiation and particle emission, the conducted heat, and the structural details of the solar-controlled interplanetary magnetic fields;

(6) Continued patrol of solar activity, at least through the coming solar minimum about 1963 or 1964, for correlation and other comparisons with data derived from researches in geophysics and space physics involving ground, balloon, rocket and satellite observations.

Dr. ROBERTS. It is a great pleasure to have a chance to talk here for a few minutes about the sun and also about the cosmic rays and their observation during the IGY.

THE SUN AND THE UNIVERSE

I think it is fair to say that when we look at the relationship between the sun and the earth, we find ourselves on the verge of completely new conceptions about the relationship of this central star of ours to the space environment. I remember some 10 years ago Dr. Hoyle in England came up with a very revolutionary suggestion, namely, that the universe is being continuously created throughout all of space and stars are being born and that throughout all of the vast depths of the cosmos new stars are coming into birth and about them probably new worlds.

I think in a sense our picture, as we look out at the sun and its effects on space, is almost equally revolutionary today. For example,

we conceive of a sun, a star, our sun, as a central body surrounded by an enormous cloud of gas, very tenuous gas, but a cloud of gas that extends out to absolutely fabulous distances, far, far out beyond the earth and Jupiter and Pluto, far out beyond the farthest planet; we know that in fact the earth is deeply embodied in the atmosphere——

Mr. THOMAS. How close to the sun? If you measure in distance away from the earth and the stars, how close to the sun?

Dr. ROBERTS. Going right to the very surface of the sun, starting out with very, very high temperatures at the surface of the sun and extending out into space. The earth, which is flying around the sun in a roughly circular orbit at some 18 miles per second, is flying through this cloud of hot gas, which has patchiness and all kinds of strange things that Dr. Van Allen and others are beginning to discover that have an influence on the conditions in the upper atmosphere of the earth.

We are just beginning to understand what these things mean. I think also that in another way the astronomer at least, viewing the IGY, thinks of it as having a significance of a philosophical sort. We are sitting here on a planet, a little, tiny hunk of dirt near a star, which is one star out of a thousand billion billion stars that come within the view of our biggest telescopes——

Mr. THOMAS. You are talking about our committee appropriation work here.

Dr. ROBERTS. We are but one of the stars, and what we see going on here has a significance for all of astronomy because this is the only sample of this kind of a life process, if you want to call it that, or a planetary process, that we can study the details of. While we may never be able to make any practical application of this knowledge as to what is going on in those hundreds of thousands of other places where there are probably civilizations and even committee meetings like this one, still it has a certain philosophical impact to know about it or perhaps to think that we know about it.

In any event, I would like to review just a few of the highlights of the solar activity and then of the cosmic ray situation as we see it.

Mr. THOMAS. Don't stop talking. You keep on. You are cutting out work for us to do for another 50 or 60 years.

SOLAR DISTURBANCES

Dr. ROBERTS. This gas, this medium, this material in space that the earth is flying through at this 18 miles a second speed varies from time to time, varies from minute to minute, in fact, and the sun is the principal body that controls this. It is only in the last few years that we have begun to realize in terms of basic physical processes exactly what the sun is emitting, what it is sending out into space. We used to know, for example, of the sunspots and their changes from day to day. I have some pictuers of great eruptions shooting out from the edge of the sun. This is my favorite. It is a picture of the edge of the sun artificially eclipsed, and this is the largest eruption ever detected. I took that picture myself in 1946. The distance from one edge of the picture to the other along the edge of that cloud of gas is over 400,000 miles. That cloud of gas shot out into space over a million miles in the course of less than an hour.

This is another picture from a few years back which shows a jet of gas shooting out along a single line far out into space carrying material out to probably the distance of the earth.

This is a picture of the surface of the sun, taken recently, showing one bright region or what we call a solar flare, which broke out. A flare which, as a matter of fact, produced an instantaneous radio fadeout down here on the earth and certain other interesting effects.

SUN-EARTH RELATIONSHIPS

We have had pictures of these features of the sun for a long time but it seems to me we are just now beginning to understand what in fact is really ejected and just how the processes of these ejections take place. We find that the sun is a variable source of several kinds of emission. First, there are X-rays and ultraviolet. When one of these enormous bursts like this takes place, the X-ray radiation apparently is increased by a very large factor. This X-ray radiation goes out into space, some of it falls on the earth and the entire sunlit half of the earth shows an effect, an effect in changing of the radio reflecting layers of the upper atmosphere, and in certain instances it means that long-distance shortwave radio communications fade out completely anywhere from a few minutes to a few hours.

Then in addition we find that actual material of the sun is fired out into space with high speed. This material, traveling maybe up to 3,000 miles a second, taking maybe anywhere from 1 to 3 or 4 days to travel from sun to earth, when it reaches earth apparently being guided by the magnetic field of the earth and falling into the north and the south polar regions and producing the aurora borealis in the northern and the aurora australis in the southern regions. Also it changes the radio output. It is a highly variable radio transmitter.

Mr. THOMAS. Will you let me interrupt a moment? Is that substance that is emitted from the sun—in what form was it when it was first emitted? Certainly after it travels through the earth atmosphere it has changed content or substance altogether, has it not?

Dr. ROBERTS. The material appears to be a typical sample of the surface of the sun, which means it is composed mostly of hydrogen, but the hydrogen atoms have the electrons stripped away from them because the temperature is high.

We would say the clouds consist mostly of protons and electrons which are really just hydrogen atoms torn apart.

Mr. THOMAS. It is not a solid mass?

Dr. ROBERTS. No, it is a gaseous cloud.

Mr. THOMAS. That is what produces the color?

Dr. ROBERTS. Yes, sir. There are two other forms of emission from the sun that we are just now beginning to get our finers on. What I am saying about these is speculative. It has come to a considerable extent out of data from the IGY, but we believe the sun's atmosphere, which we call the corona, actually conducts heat just about the way a metal bar conducts heat. So that if you hold a blowtorch under one end of a metal bar and put your hand under the other end, it is hot.

The sun appears to be hot and out here 90 million miles away, the distance of the earth, some of that heat appears to be conducted into the atmosphere of the earth. As a matter of fact, it is this process of transmission of energy which is a rather new suggestion by Dr. Chapman of the IGY, that suggests a completely new way by means of which energy can be carried from sun to earth.

Finally, we believe in terms of the forms of emission of the sun that magnetic fields of the sun are, on some occasions the magnetic forces, the portions of the sun's atmosphere containing these magnetic forces, bodily carried out from the sun and carried into space.

Now, this brings us to the two principal functions of the solar activity research of the IGY, which I am going to go over briefly because they are covered in the written testimony.

IGY SOLAR PATROLS

There are two things. One is a patrol function. The solar observatories have been on watch to observe these things and send instant warning around to all IGY stations through the very magnificent network Mr. Shapley's group has organized, so that cosmic ray physicists and the people with rockets to fire and balloons to send up and special programs to accelerate can be on guard because there is likely to be an effect at the earth in the coming hours.

BASIC SOLAR RESEARCH

The second function of the solar part of the IGY has to do with basic research in the nature of these emissions to try to find out what it is that actually reaches the upper atmosphere and how this varies from hour to hour and from day to day. This may have a considerable long-term importance in understanding, some of us think even in understanding one possible influence on weather changes, although that is very speculative and Dr. Wexler might not completely agree. Maybe he left.

Dr. WEXLER. I am listening.

Dr. ROBERTS. I thought perhaps you had left just because you knew I would say that.

So that we have maintained the special research and these patrol functions throughout the IGY.

COSMIC RAY RESEARCH

I would like to speak just for a second briefly about the cosmic ray research. I cannot cover this very fascinating story in complete detail in a few minutes, but there have been very many groups that have done brilliant work on the basis of both monitoring hour by hour, day by day, week by week, the small variations of the nature of the intensity of the cosmic rays. Remember that cosmic rays come from far out in space, most of them. They probably have been traveling for billions of years throughout the universe and then suddenly have ended up their flight in the earth's atmosphere, and we have detected them.

SOLAR FLARE EFFECTS

These cosmic rays are ordinary particles of matter speeded up to where their velocities are a large fraction of the velocity of light, which is the fastest anything can travel. Then when they get near the earth they penetrate through the atmosphere and are detected. These cosmic rays actually possess, we believe, one-half of all the energy of the universe. It is a great mystery exactly where and how these cosmic rays are formed, but we do know when the sun's activity changes the cosmic rays change. We do know that on certain rare occasions like the great occasion of the 23d of February 1956, the cosmic ray intensities increased. I remember up at Climax, the station we operate for the University of Chicago, the cosmic ray counters suddenly started counting like mad, and the fellow on duty there figured the electronic tubes had broken down and that the thing was racing away wildly. It increased more than 40 times in the number of cosmic rays it was counting and yet in fact it was an effect produced by the sun. A great ejection had occurred on the sun, these cosmic rays had come out and were streaming into the atmosphere.

So that these events—you could count them on the fingers of your hands—events when these cosmic rays are increased in this way are detected and studied in great detail all over the world. I think the 23d of February case is probably the most studied cosmic ray phenomenon that ever occurred in all the history of cosmic ray research, and the cosmic ray people therefore are very anxious to continue and extend their knowledge of the cosmic rays from these occasional rare freaks of increases of cosmic rays from the sun.

COSMIC RAY VARIATION

They are also interested to try to find out why it is that every 11 years as the sunspot activity increases the number of cosmic rays coming in from space decreases and in between the number of comic rays goes back up.

CONTINUING COSMIC RAY PROGRAM

In terms of future programs, the cosmic ray people have made some specific recommendations, the most important of which is they are anxious to see high latitude, high altitude, non-long-duration balloons monitoring cosmic rays throughout a major part of the sunspot cycle, which means from the sunspot maximum about 1958 in IGY down to something like 1964.

Secondly, they want to try to catch from a balloon one of these rare cosmic ray flares.

Thirdly, they would like to see the day by day and minute by minute monitoring of comic rays continued at least through the minimum of the sunspot cycle with something like the intensity of effort carried out in the IGY.

SOLAR MAGNETIC FIELDS

From the solar side there are a number of things that appear principally important, but the only one I am going to mention is the study

of the magnetic fields of the sun. The magnetic fields, the forces, the magnetic forces that exist in the sunspots and in the atomsphere of the sun are really great mysteries today. Their origin is a mystery and the way these magnetic fields are destroyed is mysterious.

I was in the Soviet Union on the 22d of August of this year in the afternoon looking through the solar tower telescope there, just a few hours before the occurrence of one of these great solar flares.

Mr. THOMAS. Where is the tower located?

Dr. ROBERTS. In the Crimea.

Mr. THOMAS. Way down south?

Dr. ROBERTS. Yes; in the south of the Soviet Union. They have a device which allows one to make a picture across the surface of the sun of the strength of the magnetic field. When this flare occurred, the magnetic field strength changed. We did not know that immediately at that time. I got the records later. But when the flare occurred a sudden radio noise disturbance occurred, which was observed all over the world, the biggest one, as a matter of fact, that has ever been detected.

It would be very important to have an increase in the number of stations throughout the world at which these magnetic fields can be detected. I think this is the most important problem of solar physics today, to study the nature and changes of these magnetic fields and the principal stations capable of doing this today are in the Soviet Union. I believe within a couple of years we will have to establish comparable or better equipment for this work here.

I might point out, by the way, the instrument used by the Soviets was developed by Dr. Babcock at Mount Wilson Observatory in the United States. Thank you.

Mr. THOMAS. You are wonderful. Mount Wilson is in California?

Dr. ROBERTS. Yes, sir.

SOLAR OBSERVATORIES

Mr. THOMAS. That is a great statement. We certainly appreciate your taking time out to come. How many of these stations are there in existence in the world and how many does Russia have?

Dr. ROBERTS. There were 100 stations reporting solar data to the IGY. About a dozen of these or 15 of these were in the United States. The stations doing intensive work in the United States were six. The stations doing intensive reporting in the Soviet Union, sending to our data center in Boulder, were 11.

Mr. THOMAS. Six against eleven?

Dr. ROBERTS. Yes; but some of their 11 were smaller. Our six have a great concentration of equipment.

Mr. THOMAS. On the basis of strength, who has the two strongest ones, this country or the Soviets?

Dr. ROBERTS. The Soviet effort in solar physics is very impressive in certain new fields. I would say the Crimean Observatory in the Soviet Union is probably the outstanding in the world, although the Sacramento Peak Observatory is a very, very close second. Some people might argue with my evaluation.

Mr. THOMAS. What about the one we are building in Kitts Peak in Arizona?

Dr. ROBERTS. The solar observatory is just in the early planning stages at the present time, but I believe the solar telescope planned for that station will be an enormously useful facility, but that is 5 years away.

Mr. THOMAS. Will it be 5 years away?

Dr. ROBERTS. I would guess, sir, it would be 5 years away.

Mr. YATES. Do the Russians have a bigger one than that?

Mr. THOMAS. You know what the plans and specifications are—I imagine you had a considerable part in drawing them.

Dr. ROBERTS. Yes.

Mr. THOMAS. When it is a completed unit, how will it stack up against what the Russians have and what the British have?

Dr. ROBERTS. At the present time the plans for the Kitts Peak Solar Observatory are rather specialized for one aspect of solar research, and it will be the finest telescope, I believe, in the world for that particular study. That is the study of the light from the face of the sun. For the study of the atmosphere of the sun and particularly this corona, that will not be done at Kitts Peak but will be done at the Sacramento Peak and I believe that work will be substantially improved in the years ahead. In that work we are considerably ahead of the Soviets at the present time.

My own observatory and the Sacramento Peak Observatory people offer the only accurate measurements of the sun's corona in the world today.

Mr. THOMAS. Did you plan that one in Australia, too?

Dr. ROBERTS. No; but I am familiar with it.

Mr. THOMAS. Do you prefer that location in Australia or the one in South America?

Dr. ROBERTS. Are you speaking now of the radio telescope or the solar telescope?

Mr. THOMAS. Do they have both there?

Dr. ROBERTS. They have both there.

Mr. YATES. What were we going to build in Australia?

Dr. ROBERTS. The radio telescope.

Mr. THOMAS. That is a different animal.

Dr. Roberts, you are wonderful, you are as dynamic as your subject. You come back to see us again.

STATEMENT OF ALAN H. SHAPLEY CONCERNING AURORAL STUDIES, IONOSPHERIC PHYSICS, AND GEOMAGNETISM

Dr. KAPLAN. Next we have Mr. Shapley, who is Vice Chairman of the NAS U.S. National Committee for the International Geophysical Year; member of the NAS Committee on Polar Research; member of the NAS Space Science Board; Assistant Chief of the Radio Propagation Physics Division, Central Radio Propagation Laboratory, National Bureau of Standards.

Mr. Shapley will speak about three topics. They are ionosphere, aurora, and the airflow.

Mr. THOMAS. Mr. Shapley, it is nice to have you with us and as far as this committee is concerned, you can speak on almost any subject you want to. You are one of our favorites. However, we hope you

do not give us an examination. In case you do, we want you to consider us as one of your favorites.

Mr. SHAPLEY. Mr. Thomas, my prepared testimony, which I would like to insert in the record, reviews some of the details of the early IGY results in the interrelated fields of the ionosphere, geomagnetism, and aurora and airflow.

(Mr. Shapley's prepared statement follows:)

IGY PROGRAMS IN AURORAL STUDIES, IONOSPHERIC PHYSICS, AND GEOMAGNETISM

I am very pleased to have the opportunity to discuss with you certain aspects of the early results and interpretations coming out of the three areas of IGY; high atmospheric investigation of the aurora, the ionosphere, and geomagnetism. These are, as you know, interrelated disciplines and we shall see that many natural phenomena occur which are observed simultaneously by techniques currently employed in each of the areas cited.

The U.S. program for research during the IGY in auroral studies, ionospheric physics, and for geomagnetic observations has been carried out essentially as planned. Analyses of the report from some 39 auroral observing sites and hundreds of participating amateurs who have reported auroral displays during the IGY are being actively pursued. In the ionospheric program some 37 American stations were in systematic operation during the IGY including 5 in Antarctica; cooperative studies with other countries were conducted at about the same number of stations located throughout the world. Here, too, amateurs have contributed important ionospheric data to the program. In the program for observation of geomagnetic phenomena 31 stations took part in the U.S. effort. New geomagnetic stations were established for the IGY in the Arctic, in the Pacific Ocean, in the continental United States, and also in South America with cooperation of IGY scientists in Peru.

In the report which follows there is only limited comment on those areas of research where important results have been communicated earlier. In other subjects there has been steady accumulation of data which is gradually expanding the insight of scientific investigators, but this information has not yet greatly altered the general direction of the investigations since the last report was made.

Thus in the field of ionospheric studies amplification of the work in forward scatter transmission, of backscatter results, of whistlers, and of radio noise is not made here except incidentally. Similarly, the geomagnetism program is discussed rather generally, but frequent reference to geomagnetic effects will be found in connection with phenomena reported under other disciplines such as solar activity, cosmic rays, and the aurora. In the auroral program itself detailed comment on some of the broader aspects of the program such as airglow and radar studies has been reserved in favor of a consideration of the interdisciplinary implications resulting from the great aurora of February 10, 1958.

AURORAL OBSERVATIONS

It has been reported earlier that the scheduling of the IGY for a period of expected maximum solar activity greatly enhanced the value of the IGY program, since a number of the largest solar flares resulted in extensive auroral displays. The story of the statistical frequency of auroras during the IGY is a very interesting one. The maximum number of displays observed occurred in March 1958, when there were auroras reported from stations in the United States on every day of the month except the last one. As far as is known this was the most active month of auroral displays ever recorded in the United States. Prior to March there had been a gradual increase in auroral frequency, and displays were reported for an average of 20 days for each of the preceding 4 months. For the succeeding 4 months, however, this frequency dropped to an average of 15 days reported per month. Since then the auroral activity has declined.

Visual and all-sky camera results

One particular purpose of auroral investigations during the IGY was the determination of the location of the auroral zone. Although there has not yet been time to analyze all the data certain features seem clear. One of these

concerns the east-west extent of an aurora. From volunteer reports it has been learned that if an aurora is overhead in a region where the magnetic dip (the angle between the direction of the magnetic field and the horizontal) is a certain value (for example, 70°) then everyone who can see the sky and whose dip is near that value will also be able to see the aurora. This indicates that the aurora is probably continuous on the dark side of the earth and that the zones of equal auroral frequency are roughly parallel to the lines of equal magnetic dip. The attached map shows a preliminary sketch of auroral zones for a 7-month period, including the most active month of March 1958 based on amateur observations and magnetic dip lines. The magnetic dip-auroral zone correlation is rather good in the Northern Hemisphere, but the situation is not yet clear in the antarctic regions.

The map contour labeled "70" which passes from Saskatchewan through North Dakota, Minnesota, Wisconsin, Michigan, Ontario and Quebec shows where 70 auroral displays occurred overhead during the period from September 1, 1957, to April 1, 1958 (not all might have been visible at any one location depending on local weather conditions). Similarly, the more southerly contour labeled "10" which runs from the northwestern corner of the State of Washington in an arc down through Montana, South Dakota, Iowa, and passes below the Great Lakes and out to the Atlantic above the city of New York, defines a line where 10 overhead auroras occurred during the 7-month period. Finally, the contour labeled "1" which passes through Oregon, Idaho, Wyoming, Colorado, Kansas, Missouri and eastward over the Blue Ridge mountains and North Carolina to the sea, signifies locations above which an aurora occurred once during the indicated period. Of course auroral displays were observed in regions south of this southern contour but they were seen towards the northern horizon rather than overhead. Indeed, reports from Mexico and Cuba indicate that three auroras were observed in those countries during the IGY—these included the great aurora of February 10–11, 1958.

The north-south extent of an aurora is somewhat difficult to measure from the U.S. data alone but appears to cover about 10° of latitude for a typical aurora. The position of the maximum region seems to shift during the course of a sunspot cycle. Consequently, the zones were quite far to the south during the IGY, as indicated by the accompanying map, and may now be returning northward again. As stated, the number of auroras reported seems certainly to be falling off in the later months of the IGY.

The problem of auroral motion is being studied first with the aid of volunteer reports while the laborious reductions of the many camera stations is being undertaken. If the aurora is caused by radiation coming directly from the sun one might expect an aurora, like the sun and stars, to rise in the east and set in the west, or at least seem to move from east to west. This does not seem to be the case. Spot anlayses of data for different periods of time and from Alaska, the United States and the antarctic indicate that auroral motions tend to be from west to east. The reason for this behavior is not yet known.

Other interesting things about the aurora which are now coming to light as a result of the IGY auroral mapping program are well exemplified by an aurora on the night of June 6, 1958, which was a relatively slow moving one with multiple arcs. Two homogeneous arcs about 200 miles apart which extended across North America in the Great Lakes region, broke into rayed arcs which did not become fragmented. One hour later a long sinuous arc had developed in their place. This long twisting arc was plotted from the Dakotas southward and eastward in a serpentine path which finally extended out to the ocean above the New England States.

Spectroscopic studies

First results from auroral spectroscopic investigations carried out during the IGY have now been reported. Only recently have these results become available because analysis of spectroscopic data is complex and time-consuming work. Geomagnetic records and auroral spectra were taken at Yerkes Observatory in connection with the displays on June 30, July 1, and July 5, 1957, just as the IGY began. These studies demonstrate that the horizontal component of the earth's magnetic field increases prior to the appearance of an auroral arc and that there is an inversion of the polarity of the magnetic disturbance at the time of the subsequent transition from auroral arc to rayed forms. Furthermore, the observations show that at the time of sudden transition from arc to rays there is an abrupt decrease of the intensity of light radiation charac-

teristic of hydrogen atoms in the high atmosphere which contribute to the auroral display. These data have been interpreted to suggest that there are two separate current systems associated with auroral display—one responsible for the acceleration of auroral protons and electrons by which arcs are excited into visibility and the other for the acceleration of auroral electrons which cause excitation of displays of more active types. Of course, much further corroborative evidence is required before this picture can be verified.

A new twilight phenomenon, the presence of radiation from the sky at a wavelength of approximately 6,708 Angstrom units, was discovered in spectra taken at antarctic stations during the last few months of 1958. This radiation was first reported by the joint New Zealand-U.S. station at Cape Hallett on August 5, 1958, and has been observed at other U.S. antarctic stations, and also at the New Zealand station of Invercargill. It has been attributed to the presense of lithium in the high atmosphere, a constituent not previously known to be present there. This twilight display is analogous to the twilight radiation often observed from sodium in the high atmosphere. A plain inference is that the new lithium displays could be related to nuclear tests carried out during the same period as the IGY program.

An artificial aurora

One of the unexpected phenomena during the IGY was auroral displays seen to the west and north at Apia, Samoa, by New Zealand observers on August 1, 1958. This was quite surprising since Apia is situated only 16 degrees south of the geomagnetic equator (13° S. latitude), while the auroral zone maxima are about 65 degrees geomagnetic. The display lasted for some 6 to 7 minutes and has been tentatively explained as a result of a nuclear explosion above Johnston Island some 2,200 miles away. A recent letter in the British science journal Nature suggests that the auroral display at Apia was caused by the injection of energetic electrons into the atmosphere by the explosion at Johnston Island; the electrons then followed or spiraled about the magnetic lines of force to impinge again on the denser atmosphere in the region where the aurora was observed.

The great aurora of February 10, 1958

The interdisciplinary value of the simultaneously conducted IGY sutdies, which has been referred to, is perhaps most strikingly indicated by the cosmic events on February 10–11, 1958. This was a very outstanding display of aurora, with an unusually sharp magnetic storm and other related phenomena.

Balloon-borne instruments at Minneapolis deected two groups of strong X-ray bursts during the storm. These coincided with two large magnetic bays (increases or decreases in the intensity of terrestrial magnetic-field components, represented by baylike indentations in graphs showing variations of magnetic intensity with time); with strong absorption of radio noise; and with the passage across the zenith of a very large amount of auroral luminosity. A cosmic ray decrease also accompanied the storm. University of Minnesota workers believe that these terrestrial disturbances were associated with the earth's entry into a large cloud of solar gases that may have originated in a solar flare which occurred a day earlier.

The aurora observed in North America during this storm was one of the most spectacular in recent years. As stated above it was seen from areas as far south as Cuba. At Minneapolis, the aurora was seen by visual observers simultaneously with the sudden commencement of the magnetic disturbance, at 7:26 p.m. c.s.t., February 10. The all-sky camera record from Hanover, N.H., shows its appearance a few minutes after the magnetic disturbance began. At Minneapolis, for the next 2 hours a very intense, diffuse, and broad green arc covered the sky from 20 degrees above the northern horizon to the zenith and from the eastern to the western horizon. Another outstanding feature was a red glow, also very intense, which appeared in diffuse patches at high angles above the northern horizon. This was even visible from midtown Washington, through haze and the glow of the city lights. At 8 p.m. from Minneapolis it covered the northern sky from 15 to 30 degrees elevation as a diffuse arc.

It is estimated that the aurora extended up to a height of about 500 miles above the earth and for a distance of about 6,000 miles east-west and 250 miles north-south. In addiiton to the very high intensity of both the red and green spectral lines, other unusual features of the aurora were the diffuseness and extent of the luminescence, and its persistence for long periods without major changes in form.

Considerable solar activity was present for several days prior to the terrestrial storm; hence the solar-terrestrial relationship is not completely certain. However, the outstanding solar event of the period was a class 2 flare, first observed by Honolulu and Sacramento Peak (N. Mex.) observatories cooperating in the IGY program a little more than 28 hours prior to the display itself. Large radio-noise fluxes were reported by several statiosn during the flare.

When the terrestrial magnetic effects of this storm began, the Fredericksburg (Va.) Magnetic Observatory recorded data which show that the initial bay in the horizontal component of the earth's magnetic field was followed by a second sharp bay of opposite polarity some 30 minutes later. This very large increase in the horizontal component was accompanied by fluctuations in the vertical component of the magnetic field and in the magnetic declination also. It has been assumed that these pulses represent the initial encounter of the solar gas cloud with the earth's magnetic field, the sudden development of ionospheric electric current systems, or both. The indicated transit time from sun to earth of 28 hours for solar corpuscular streams lies within the range of values often postulated for the speed of such streams.

It is interesting to note that large electrical currents within the earth were observed during this magnetic storm coincident with the first large increase in the horizontal component of the earth's field: this occurred 33 minutes after the disturbance began. The effect on earth currents is exemplified by the observation that the electric potential on the transatlantic telephone cable from Newfoundland to Scotland reached a maximum of 2,650 volts. It then fell through zero to a peak in the opposite direction some seven minutes later. Lesser effects were noted on a cable from Washington State to Alaska: none at all were seen on a cable from California to Hawaii. According to the observations, the recorded current flow was from west to east. Interpretation of this and the related magnetic effects implies that the earth current was apparently part of a system flowing in the earth's surface and associated with changes in the vertical component in the magnetic field in an as yet unexplained way. The current system seemed to be strongest in the Eastern United States.

Balloon-borne equipment launched at Minneapolis picked up bursts of X-rays in the high atmosphere at 22 minutes after midnight, Febraury 11, coincident with a major decrease in magnetic intensity during the second phase of the storm. These bursts continued for the next several hours. It has been suggested that both changes in the electrical conductivity of the ionospheric E-layer which produced the magnetic effects, and the observed X-rays had a common origin in electrons produced by the solar gas stream. Furthermore, a large absorption of 18 mc./sec. cosmic radio noise observed from the ground, after passing through the ionosphere was detected exactly coincident with the magnetic bays and X-ray bursts. This absorption observed with various types of equipment at Boulder, Colo., and elsewhere gave evidence of a widespread increase in ionospheric electron density extending far to the north and south. Correspondence of data from the stations at Fredericksburg, Minneapolis, and Boulder, shows that the major primary fluctuations were simultaneous over distances of thousands of miles. All these changes—in the horizontal component of the magnetic field, in cosmic noise absorption, in auroral X-rays, and the general presence of the aurora itself—are consistent with intensified bombardment of the ionosphere by high energy electrons over the Central United States.

This auroral storm was accompanied by still another geophysical manifestation: a worldwide decrease in the intensity of galactic cosmic rays. Recordings of ground level instruments in Europe and Africa along the longitude of Greenwich, and in North and South America all showed an initial drop about 34 minutes after the first magnetic disturbance. High altitude balloon observations of cosmic ray energy showed that the initial decrease had only recovered by less than half on February 16.

Evaluation of all these data has shown that they are consistent with the passage of the earth into a remarkably intense solar cloud on February 10. This cloud may have originated on February 9 in the solar flare cited. The major terrestrial magnetic effects were over within 24 hours after the first magnetic disturbance, so that it is assumed the earth was clear of the cloud by that time. The flare lasted about 2 hours; and if the cloud originated within this interval and required 24 hours to pass by the earth, the individual particles of the cloud must have acquired a wide range of velocities during its passage. Thus, it has been inferred that when the cloud was near the earth it extended over a distance equal to half that from sun to earth. The leading edge of the cloud must have been exceedingly well defined and of the order of an earth's radius across.

According to this interpretation, the trailing portion of the cloud had more diffuse boundaries, while the geomagnetic and X-ray data imply that the main body of the cloud contained irregularities of internal structure maintained during the sun-earth passage.

Finally, more precise information on the interaction of cloud and terrestrial atmosphere is provided by auroral spectrograms taken at College, Alaska, during this display. They have been subjected to detailed analysis which reveals high abnormal vibration of ionized nitrogen molecules in the high atmosphere. Examination of the spectral records of light emitted from hydrogen atoms during this display has shown also that hydrogen was present in great abundance and was arriving in the atmosphere at possibly a somewhat slower speed than usual. Moreover, there was enhancement of spectral lines emitted by atomic oxygen in the high atmosphere. The display itself was from an unusually high altitude and was unusual in its diffuseness. On the basis of these unusual auroral features, it has been suggested that the aurora was caused by an abnormally plentiful influx of protons whose average energy was lower than usual.

The many aspects of the February 10 aurora have been cited to show the great value of the synoptic approach adopted for the observational programs of the International Geophysical Year. In this instance the phenomena observed at many locations around the world, and by many scientific techniques, have all contributed to the formulation, incomplete as yet, of a picture of the solar gas cloud and its effects on the earth passing through it. The spectroscopic and visual auroral data, and those from geomagnetic, cosmic ray, and cosmic radio wave absorption studies, together with the observations of X-rays by balloon-borne equipment, have all been used to enrich this picture of the mechanism of the interaction of the terrestrial atmosphere with the solar cloud. Nevertheless, before these data will have been fully useful, they will have been employed with the observations of other events, yet to be analyzed or recorded, to formulate a more detailed and rigorous description of the phenomena which will stand as fully accepted theory.

IONOSPHERIC PHYSICS

Vertical soundings

It has earlier been reported that analyses of the radarlike probings of the ionosphere 50 to 200 miles overhead, made at selected groups of stations, have thrown light on some problems but have also raised new questions. In the polar regions, for example, it was discovered that the upper air F-layer in the ionosphere persists throughout the polar night although its ordinarily rather uniform structure seems to break up into cloud formations. Furthermore, daily variation of the degree of ionization at the South Pole has been discovered even though the sun is always at a constant height above or below the horizon. A number of similarities and differences between north and south polar regions have also been delineated. The remarkable lack of close correlation between the sun's position and the condition of the antarctic ionosphere will be clarified more fully as additional data are collected.

Some questions of polar ionospheric behavior of great interest which remain to be investigated in detail include the following:

(1) A theoretical explanation for the observed ionospheric daily variations at the South Pole is desired. The year-round 12-hour variations may indicate that atmospheric tidal effects play an important role.

(2) More complete study of an apparent ionospheric anomaly which exists in the Palmer Peninsula area should be carried out. This is a unique antarctic region of very low magnetic dip (58 degrees at Port Lockroy) considering the relatively high geographic latitude (65 degrees S.). It seems likely that the inverse daily ionospheric variation observed in this area in the summer is associated with this anomalous magnetic condition and is not a true difference from data obtained in the Northern Hemisphere.

(3) Ionospheric storm effects in the two hemispheres should be compared in greater detail, e.g., a preliminary study of two ionospheric storms in August and September of 1957 show that storm effects were generally observed 3 to 5 hours earlier in the Arctic than in the Antarctic.

A close-spaced chain of sounding stations established for the IGY in South America has been used to determine better the nature and extent of the ionospheric anomalies occurring in the equatorial region. Four of the stations were operated cooperatively with the Peruvian participating committee and the fifth with the Bolivian participating committee. The data have been used to provide information on the maximum electron density in the high F layer of

the ionosphere, distribution of electron density with altitude along the chain, the occurrence of a special type of equatorial turbulent condition in the F layer, and the occurrence of the high density elcctron concentrations in the E region, known as equatorial sporadic E.

The maximum electron concentration data suggest that a rather strong horizontal gradient of ionization density often exists across the magnetic equator in the late evening at the 125–250 mile level. Probably the most striking feature of the electron density data is the low electron density which occurs daily between 6 and 9 p.m., just after sunset. The decrease appears to be too large to be accounted for alone by the recombination of the electrons with positive ions. The turbulent conditions in the F-region of the ionosphere which were observed in the autumn seem to occupy a broad belt centered roughly on the equator of magnetic dip and extending about 10° to the north and south from it. The time of occurrence of these disturbed conditions is apparently correlated with the appearance of activity in the magnetic records. Results to date suggest furthermore that there is a close tie between the sporadic-E clouds of ionization at lower altitudes in the ionosphere and the equatorial electrical current system, particularly the electrojet.

True height reductions

It has been noted that the reduction of vertical echo sounding data to actual electron density as a function of altitude has been a difficult theoretical problem because the probing radio waves are slowed down and bent in a complicated way during the journey to the ionosphere and back. This mathematical problem has been compared to the problem of deducing the contour of a hill from observations of the time needed for a ball to roll down it from various heights. The two problems are mathematically identical if the effect of the earth's magnetic field is neglected. If it is included, the ionospheric problem is even more complicated. The development of techniques permitting this reduction to be carried out rapidly and with reliability during the IGY by use of machine computers has already provided very interesting results.

It has been noted above that electron densities decrease at sunset in Peru, as expected, but that subsequently they rise and may even exceed the noontime values. This result cannot be explained by the ordinary photochemical theory of the ionosphere. Furthermore, the density of ionization in the F–2 layer, as it varies with height, rarely corresponds to a parabola, as has sometimes been suggested on the basis of such simple theory. The increase in maximum electron density at night particularly in Peru and Panama is thus not the effect of some unusual ionizing source but rather the result of downward layer movement which compresses the ionosphere. This vertical motion seems to be due to the interaction of horizontal tidal winds with the earth's magnetic field. The general effects are clear, but a quantitative theory is still lacking.

Electron density profiles for many stations at a few times (rather than for many times at a few stations) have also been carried out to determine the instantaneous horizontal distribution of electron density at a series of fixed heights over the United States. Applications include the interpretation of radio data from satellites or other sources within or beyond the ionosphere, the determination of paths of radio waves reflected at oblique incidence from the ionosphere, the study of regional anomalies in the ionosphere, and the study of large traveling disturbances there. A collection of such profiles for stations in and near the continental United States during a number of months of the IGY has now been produced by the Central Radio Propagation Laboratory of the National Bureau of Standards.

Sporadic-E studies

An earlier report has described the IGY project in which signals scattered from sporadic–E ionization are being recorded on radio circuits in the Far East and in the Caribbean. From Far Eastern work it has been discovered that there is a sudden enhancement of the radio signal strength which commences about two hours after sunset and continues until about midnight appearing particularly strong during the autumnal equinox. Interestingly enough, these signals have some of the same characteristics as echoes returned from extensive auroral curtains. It has been suggested that in both cases there are blobs of ionization in the high atmosphere which are oriented along the earth's magnetic field.

Radio amateur program

The assistance of radio amateurs has been important in providing information on the propagation of radio waves reflected from sporadic–E clouds of ioniza-

tion in the E region, and on propagation of waves scattered from inequalities in the electron concentration in the ionosphere. Propagation by scattering from meteor ionization trails and by reflection from auroral irregularities is also observed on amateur radio circuits and reported. The amateur data are a very useful supplement to data from the IGY observational networks formally organized to explore these phenomena.

Over 550 amateurs representing nearly 50 countries have taken an active part in this program of ionospheric observations. They have submitted semi-monthly reports of the stations contacted or heard by means of the various propagation modes. Through their efforts it is possible to achieve an overall picture of worldwide propagation conditions during the IGY that would be difficult to duplicate by any other means. The analyses of the amateur data collected is accomplished by punch card collation techniques and high speed automatic data handling employing machine computers. During the IGY an average of almost 10,000 cards per month was required to document the items reported. The work of the American radio amateurs has been especially valuable in connection with the scatter propagation studies carried out on South American signals during the IGY. The unusual propagation conditions present there were first noted by amateurs during the last sunspot maximum. Similar work has been done for the first time by amateurs on circuits between Japan and Australia and between southern Europe and the Rhodesias.

Absorption studies

The measurement of the degree of absorption in the ionosphere of radio signals received from cosmic sources has been carried out at a network of stations as a joint ionosphere-auroral program. It has been found, for example, that in Alaska, during the spring of 1958, the maximum of the absorption zone was located at about the latitude of College. The average amount of absorption fell off more rapidly to the south of College than to the north, indicating that the absorption zone is asymmetrical about its maximum. Comparison of absorption measurements at Alaskan stations shows that the absorbing layer can be considered no more than approximately uniform over a distance of some 150 miles. For this period of the IGY the maximum amount of ionospheric absorption occurred between midnight and 4 p.m. local time. The remaining time from 4 p.m. to midnight was usually quiet even on days of relatively great ionospheric disturbance.

GEOMAGNETISM

The major portion of the earth's magnetic field is thought to be generated by electric currents within the earth. The remaining portion, about 5 percent of the field, is generated externally, it is believed, by great, globe girdling systems of electric currents in the charged, or ionized regions of the upper atmosphere. The earth-generated part of the field is relatively stable, undergoing slow changes measured in years, tens of years, and even centuries. The externally generated part of the field is characterized by rapid, or transient fluctuations measured in days, minutes, and seconds. It is with these transient fluctuations that the IGY geomagnetic program has been mainly concerned. Daily variations in the magnetic field are believed to be tidal (solar and lunar) in origin. Other rapid fluctuations and disturbances may result from the entry into the earth's upper atmosphere of energetic ionizing radiations, and high velocity electrically neutral streams of corpuscles. Both these effects are related to explosive activity on the sun and result in manifestations in the atmosphere which affect measurements in other high atmospheric investigations carried out under the IGY program.

Geomagnetic observatories were installed for the IGY at four Antarctic stations and have furnished material for the study of magnetic storm conditions as a worldwide phenomenon—allowing comparisons with the records obtained in the equatorial and north polar regions Geomagnetic observations were also conducted on IGY Drifting Station A in the Arctic Ocean icepack during the period it was occupied.

Near the magnetic equator the daily variation in the horizontal component in the earth's magnetic field has been found to be unusually large. An earlier observational program organized in 1949 to study this variation indicated the existence of a narrow band of concentrated electric current flowing eastward in the upper atmosphere during midday. This current—the equatorial electrojet—is superposed on a more diffuse current distribution which accounts for normal quiet day magnetic variations. To determine the extent of electrojet

effects a number of IGY stations were occupied on the west coast of Peru in cooperation with Peruvian scientists.

It was discovered that a maximum daily variation in the vertical component of the earth's magnetic field occurred at about 16° S. and another maximum with an opposite sign occurred at 8° or 9° S. The north-south distance of 500 miles between these extremes provides a rough estimate of the width of the electrojet band, which straddles the magnetic equator situated at about 12° S. in those longitudes. To estimate reliably the height and width of the electrojet, the electric current system of the electrojet must first be derived; but, to accomplish this, normal variations, estimated from locations free from the influence of the electrojet, must first be subtracted. Such height and width estimates have not yet been completed but are actively being pursued.

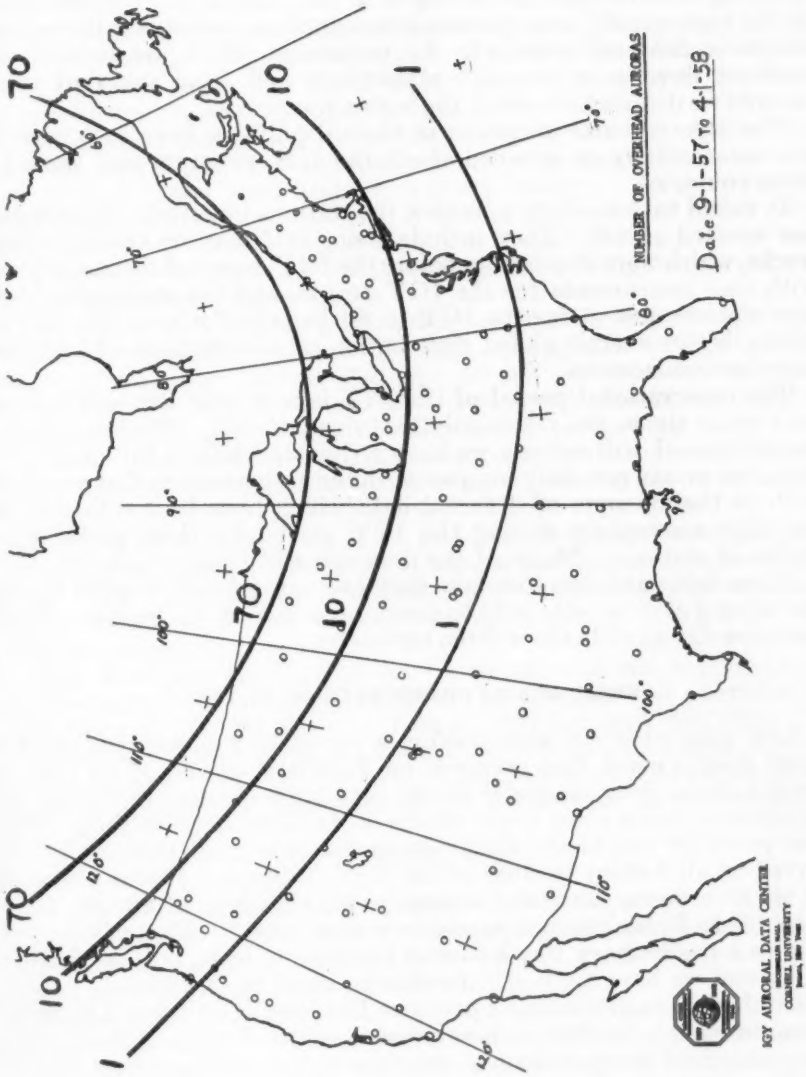
Stations in the Pacific Ocean—at Guam and Koror in the western Pacific, and at Jarvis, Palmyra and Fanning Islands in the eastern Pacific—were established especially to confirm the existence of and study the electrojet in other longitudes. The site for the Koror Observatory in the Palau Islands was chosen with the intention of establishing a recording station as near as possible to the magnetic equator. Not until the observatory was actually in operation was it realized how closely that objective had been achieved. At Koror, the vertical component of the earth's field is downward during part of the day and upward during the remainder.

Preliminary analysis of records from Koror suggests that the source of markedly enhanced geomagnetic disturbance—the equatorial electrojet—lies slightly north of the observatory, perhaps as far as 60 miles, for at least part of the year. Preliminary inspection of records from the other Pacific islands tends to support observations made elsewhere of the concentration of electrojet effects in the vicinity of the magnetic equator.

SUMMARY

It will be apparent from this very brief description of work accomplished and analysis currently in progress that new insights into the structure and behavior of the high atmosphere are being gained as a result of the IGY observational program. In the months to come it may confidently be expected that still greater understanding will be achieved through use of the very great fund of data at hand. As just one example of the very necessary amount of time needed to develop useful theories from analysis of the data one may cite the fact that the first papers interpreting spectroscopic observations of auroras which occurred at the beginning of the IGY have only just been published. This is not an isolated example of the time required to interpret data usefully once it is at hand. Moreover, it should be pointed out that in many cases the IGY data will not be assembled in useful form for analysis until still more time has elapsed. The international auroral maps, for example, will only be available, at best, sometime later this year for general dissemination to those waiting to study them. Thus, there are many active investigations underway which will make use of IGY data already obtained but still being collected.

As the analysis of results proceeds new questions arise which suggest further experimentation. Plainly, the analytical activity concurrent with the observational program during the IGY has already pointed to new areas of investigation. Some of these are apparent from just a cursory perusal of the phenomena recounted above. The why of daily ionospheric variations in the absence of sunlight in Antarctica, the delineation of the mechanism responsible for auroral current streams, and explanation of the causes of equatorial electrojet morphology are just three examples of problems in each of the three areas of investigation discussed above which are imperfectly understood and which will certainly require many additional analyses and observational data before they can be interpreted.


NUMBER OF OVERHEAD AURORAS
Date 9-1-57 TO 4-1-58
70
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IGY AURORAL DATA CENTER
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Mr. SHAPLEY. You will recall that these disciplines study different manifestations of the interaction of the earth's magnetic field and of the high atmosphere on the one hand with radiation and particles coming to the earth from outside.

The aurora and airflow is studying the light radiation from excited atoms in the high atmosphere. Ionospheric physics involves studying distribution and changes in the number of free electrons in the high atmosphere, whereas geomagnetism is studying the earth's magnetic field and especially its variations, which are induced by currents flowing in the high atmosphere and from study of these records we deduce facts about the high atmosphere.

The observational programs in these disciplines have been carried out substantially as planned—both the U.S. program and those of other countries.

It would take too long to review the stations involved. They number upward of 400. They include about half that are the basic networks, which were in existence before the IGY, many of them equipped with new instruments for the IGY period, and the remainder were new stations put in for the IGY to fill gaps in the networks and to give a better overall global distribution of observations of high atmosphere phenomena.

The observational period of the IGY is now over, but as has been said many times, the job is only half done, if that. We have many, many data—I will not say we have a thousand billion billion bits of data, but we can certainly compete with the high numbers that you deal with in the amounts of different data which have been collected on the high atmosphere during the IGY period by these global networks of stations. Many of the data are still being processed.

These fields are ones that take slow and careful and detailed study. So today I will be able only to touch on a few of the results. They are more discussed in the written testimony.

GREAT AURORA OF FEBRUARY 10, 11, 1958

Last year when we were making a report to you, we mentioned a great cosmic event that occurred on February 10 and 11 of 1958, a great aurora, great magnetic storm, very large changes in the earth's ionosphere, and a great many effects on radio communications. This was probably one of the disturbances that was most thoroughly observed in all history because of the IGY coverage. It was observed in all its aspects, the visual aurora, radar sightings of aurora, magnetic field effects, ionosphere, cosmic rays, et cetera. Most of what we said in a preliminary way last year has proved to be true on further study and we have made still further progress in that time.

I do not have as authentic props as Dr. Revelle had, but I thought I would stretch out for you here a record of the changes in the earliest magnetic field at one station at the time of this storm, so you can get an idea of such a cosmic disturbance. This is a time scale, these are hours, so that from the left-hand edge of the record to here is about 20 hours, I believe.

The strength of the earth's magnetic field or, if you like, you could visualize it as the direction the compass needle would point in, stayed about constant throughout these hours before the storm started. You can see that here very abrutly something changed in the intensity of

the earth's magnetic field. This then is the duration of the magnetic storm, lasting for 24 to 36 hours, including some very violent fluctuations. The compass needle, if you were watching it carefully, might have veered as much as 5° during a change of this sort.

This is a rather unusual storm. It is one of the most intensely active periods we have had during the IGY.

At the same time that these changes were taking place very drastic things were happening to the earth's ionosphere. There were X-rays observed coming into the atmosphere in unusual intensities. At the time this was happening other things were happening in the ionosphere during these other major changes.

Throughout this period the northern lights were very spectacular all over the world but especially there were favorable observing conditions in the United States and North America. At the time this was happening aurora was seen in Mexico City and in Cuba. Mr. Odishaw and I were looking at the sky at about this time and we saw, even through the haze of Washington and the city lights, we saw red aurora up in the northern sky.

This gives an idea that nature does undergo drastic changes, and here is a graphic illustration of the type of thing that we are studying in these programs. I will also pass around for your interest some sample records of the aurora taken during this disturbance so that perhaps you can get a better feel of what we are looking at.

These circles here are looking down a spherical mirror, looking down from above on a spherical mirror, which will therefore reflect into your eye the light from all the sky.

In the first pictures here, these pictures are taken 1 minute apart, the sky is dark, with a little bit of aurora showing in a corner of the sky. Then in just a few minutes, 2 or 3 minutes, the aurora built up until 4 minutes after the start of this illustration the aurora covered the whole sky.

This illustrates the type of drastic change that can happen in the northern lights during one of these disturbances and provides the raw material for the studies which started the next day after that aurora and are still going on, both of the ionospheric effects, auroral effects, magnetic effects, et cetera. This then is an illustration of the type of phenomena that involves the joint study in these various disciplines.

NEW WHISTLER DISCOVERY

As an illustration of another effect that could not have been discovered if there had not been a widespread global network of observing stations is a new discovery that has just, I think today, been published of what is called a worldwide whistler.

Perhaps you may remember at some earlier reports we discussed these things called whistling atmospherics. What happens is there is a lightning stroke and the radiation, electromagnetic radiation, goes out in all directions from the lightning stroke. Some of the radiation is channeled along the lines of force of the earth's magnetic field that go out thousands of miles into space and then come back in the opposite hemisphere. In the course of this energy that goes along this path, the energy is dispersed, so instead of hearing ordinary static at the far end of this path, the energy is spread out in frequency so that a whistle is heard instead of the lightning stroke itself, being a click.

What is received in the opposite hemisphere, after propagation along the whistler mode, is a whistle.

This was the simple theory, the earlier theory, and so whenever there was a thunderstorm of a certain type with lightning crashes, these whistlers would be generated and they could be observed at the other end of the magnetic field line.

I think it was last year that I reported to you that the same whistler had been observed over quite an area of the Northern Hemisphere. The same whistler was observed at Stanford, Calif., and Anchorage, Alaska, which indicates that the channeling of the energy is not too accurate.

Since then it has been ascertained by studying the IGY results that have come in from a whole network of stations that there is at least one whistler which was observed over such a wide area that we could perhaps call it a worldwide whistler. It was observed in New Zealand, simultaneously in Alaska, in Stanford and Bermuda, Washington, and presumably it was observed everywhere.

There is no explanation for this phenomenon. It is a brandnew phenomenon.

The point I want to make is it would never have been discovered if we had not had for the IGY a dispersed network of stations whose observations were coordinated in time very carefully and if we did not have a system or arrangement for bringing the records from all these stations to a single place.

FUTURE ACTIVITIES

I would like to say a few things about the future in these fields of science. There was cooperation in geomagnetism, in ionosphere, in aurora before the IGY. The observational work was fairly low-level activity. The interchange and contacts scientists had were on a much slower time scale than we have had during the IGY. But these scientists in these disciplines will want to cooperate and are cooperating after the IGY. There are many more people involved on account of the stimulus the IGY has given to these fields. There are more stations involved.

Again, the observational actvity will undoubtedly be lower than the IGY. Even scientists have a limited amount of strength. We cannot work each and every Sunday, year in and year out. A tremendous effort was made during the IGY and a reasonable effort will be continued after the IGY. However, it will not be on quite such a high scale. There are strong needs that the efforts that we put into this kind of observation after the IGY be done in an orderly and balanced fashion and coordinated as has been done during the IGY.

ICSU SPECIAL COMMITTEE FOR GEOPHYSICS

An international framework has already been set up for this in the Special Committee on Geophysics, established under the International Council of Scientific Unions. It is, in effect, the successor committee to the Special Committee on Geophysics; the International Special Committee for the IGY.

I happen to be a member of both of these committees. Dr. Berkner, as you know, was Vice Chairman of the Special Committee for the IGY and will also be serving on the continuing Special Committee on Geophysics.

The international framework is in hand and several countries have specified programs for the continuing work. It is called IGC 1959. IGC stands for International Geophysical Cooperation.

The U.S.S.R. in particular has prescribed and outlined a program to be carried out in IGC 1959. The U.S. program as yet is still taking shape.

The point I want to make here is that it seems essential to use and maintain the framework, even though the world cannot sustain the level of activity of the IGY indefinitely, but they should make use of the framework that provides for active coordination of observations, for the flow of data to data centers, for continued active cooperation with our colleagues.

Only in this way can we make the most of the observations that are taken in the years to come and only in this way can we have an orderly, planned package, if you will, program in geophysics.

I think that is all that I want to say.

Mr. THOMAS. A wonderful statement.

Thank you so much, Doctor.

STATEMENT OF DR. JAMES A. VAN ALLEN CONCERNING ROCKETS AND SATELLITES

Dr. KAPLAN. We now come to Dr. James A. Van Allen, who was with us, as you will recall, a couple of years ago.

Dr. YATES. He is the one who brought in the "basketball."

Dr. KAPLAN. As you know, Dr. Van Allen is the head of the Department of Physics at the University of Iowa. He will talk about rockets and satellites.

Mr. THOMAS. Thank you, Doctor.

We are delighted to have you. You have been sort of neglecting us here of late.

Dr. KAPLAN. May I add just one more word to the introduction?

Mr. THOMAS. Surely.

Dr. KAPLAN. I had the pleasure of being present recently when the Army decorated Dr. Van Allen and Dr. Pickering, two members of our technical team.

He is too modest to say, but in his left lapel is the decoration.

Mr. THOMAS. He deserves it and we congratulate you and the Army for having the good judgment to do that.

Doctor, do not neglect us now. You have not been with us for 6 or 7 months and you must come to see us more often. We are anxious to hear from you and we do not want to lead the witness but your most recent achievement is now less than 24 hours old.

Tell us about it.

(Dr. Van Allen's statement is as follows:)

Mr. Chairman and members of the committee, I am indeed honored to be here today to discuss with you the program of scientific observations undertaken with rockets and satellites by U.S. scientists for the International Geophysical Year. Rockets and satellites are some of the most useful tools developed recently for scientific exploration of the upper atmosphere and near space.

Besides the United States, rocket programs were conducted by Australia, Canada, France, Great Britain, Japan, and the U.S.S.R. In recent years, small easy-to-handle, and, most importantly, inexpensive rockets have been developed, and we may look to ever-increasing research using this technique, and hopefully to the entry into this field of geophysics of many other countries.

Both the U.S.S.R. and the United States were successful in placing instrumented satellites in orbits around the earth, and in firing scientifically equipped rocket probes into near space. The satellite as a vehicle is capable of carrying sophisticated equipment, data storage devices, and long-lived telemetering transmitters made possible through the rapid development of solar batteries. The satellite, if of the proper shape and placed in a suitable orbit, is also a most useful scientific instrument in itself as it is a celestial body on which we can make precise and often repeated observations of positions. Some of the interesting scientific results derived thus far from the satellite program are derived from observations of the satellite orbits.

I. U.S. Rocket and Satellite Program

Rocket program

The various agencies that participated in the U.S. program in rocketry for the IGY are Air Force Cambridge Research Center, U.S. Army Ordnance Ballistic Research Laboratories of Aberdeen Proving Ground, U.S. Naval Research Laboratory, U.S. Navy Bureau of Ordnance, New Mexico College of Agriculture and Mechanical Arts, U.S. Army Signal Research and Development Laboratories, State University of Iowa, University of Michigan, and the White Sands Signal Agency.

U.S. rockets were fired at locations ranging from the Arctic to the Antarctic. One of the most important achievements of the program was the establishment of the rocket-firing facilities at Fort Churchill, Manitoba, Canada, located at a strategic magnetic latitude for studies of the electrical properties of the upper atmosphere. U.S. rocket scientists cannot express too eloquently their appreciation for the enthusiastic interest and cooperation of the Canadian Government, which made possible the establishment of this facility.

Other locations and a preliminary list of the actual firings are presented in table I. In addition to those listed, some rockets were also fired, mostly for test purposes. Occasional instrumental problems of rescheduling because of weather resulted in the postponement of several planned firings, which may possibly be accomplished early in 1959.

SATELLITE PROGRAM

Last year, in the review before this committee of the first 11 months of the IGY, Dr. Richard Porter, Chairman of the Technical Panel on the Earth Satellite Program of the U.S. National Committee, reported on the satellite program and presented a summary of IGY satellites launched as of May 28, 1958. Table II shows the present accounting of the satellite program as of February 10, 1959. There are still three instrumented satellite packages in the Vanguard program and these are scheduled for launching attempts in the first half of 1959. In connection with the Vanguard program, it is important to note that 1958 Beta, Vanguard I, is still in orbit and, while it carries a minimum of internal instrumentation, the tracking of the orbit has produced scientific information of great interest and importance. It and the new Vanguard satellite are the only satellites yet launched, either by the United States or by the U.S.S.R., which has a configuration and orbit required by geodisists to calculate quantities dealing with the earth's shape and gravitational field. The satellite successfully launched yesterday, 1959 Alpha, opens up a new era for meteorological research.

TABLE I.—*Preliminary estimate of IGY rocket firings*

Locality	Number of rockets		
	Pre-IGY (July 5, 1956–June 30, 1957)	IGY (July 1, 1957–Dec. 31, 1958)	Total
Fort Churchill, Canada	7	89	96
Point Mugu, Calif.		20	20
White Sands, N. Mex.	2	4	6
Holloman Air Force Base, N. Mex.	2	2	4
Guam, Pacific	3	9	12
Eclipse, Pacific		8	8
Other shipboard (Arctic, equatorial, Antarctic)	15	54	69
Wallops Island, Va.	1		1
Total	30	186	216

TABLE II(a).—*U.S.-IGY satellites*

	1958 Alpha (Explorer I)	1958 Beta (Vanguard I)	1958 Gamma (Explorer III)	1958 Epsilon (Explorer IV)	1959 Alpha (Vanguard II)
Weight (pounds)	30.8	3.25	31	37.10	21.5.
Shape	Cylinder	Sphere	Cylinder	Cylinder	Sphere.
Dimensions	80 inches long; 6 inches in diameter.	6.4 inches in diameter.	80 inches long; 6 inches in diameter.	80 inches long; 6 inches in diameter.	20 inches in diameter.
Shell composition	Steel with 8 aluminum oxide stripes.	Aluminum	Steel with 8 aluminum oxide stripes.	Stainless steel	Magnesium.
Antennas	1 turnstile antenna with 4 whip elements each 22.5 inches long; 1 dipole antenna using the skin of the satellite itself.	1 turnstile antenna and 1 dipole antenna with total of 6 12-inch rod elements.	2 dipole antennas using the skin of the satellite itself.	2 dipole antennas using the skin of the satellite itself.	1 turnstile antenna with 4 30-inch spring-loaded elements.
Experiments	10.63 pounds: 1. cosmic rays; 2. micrometeorites, (a) microphone and (b) gages; 3. temperatures, (*a*) internal, (*b*) rear skin, (*c*) front skin and (*d*) nose cone.	1.06 pounds: temperatures.	10.83 pounds: 1. cosmic rays with tape recorder feature; 2. micrometeorite gages; 3. temperatures (a) skin and (*b*) internal.	18.26 pounds: 2. Geiger-Mueller counters and 2 scintillation counters to measure corpuscular radiation at several intensity levels.	12 pounds: 2 infrared photocells to scan the earth's cloud cover; temperature of instrument package.
Transmitters	(*a*) 108 megacycles at 10 milliwatts (1, 2(*b*), 3(*c*) and 3(*d*), above) (*b*) 108.03 megacycles at 60 milliwatts (1, 2(*a*), 3(*a*), and 3(*b*) above).	(*a*) 108 megacycles at 10 milliwatts; (*b*) 108.03 megacycles at 5 milliwatts.	(*a*) 108 megacycles at 10 milliwatts (1, 2, 3(*a*) and 3(*b*) above) (*b*) 108.03 megacycles at 60 milliwatts (1 only).	(*a*) 108 megacycles at 10 milliwatts; (*b*) 108.03 megacycles at 60 milliwatts (each transmitter broadcasts all 5 channels of information simultaneously and continuously, although (*a*) is primarily for tracking).	(*a*) 108 at 10 milliwatts (*b*) 108.3 at 1 watt (*a*) for tracking only; (*b*) transmits stored data upon interrogation.
Transmitter lifetime	(*a*) Ceased operating May 23, 1958; (*b*) ceased Feb. 11, 1958, began again Feb. 24, ceased finally Feb. 28.	(*a*) Ceased operating Apr. 5, 1958; (*b*) will operate indefinitely.	(*a*) Telemetering and beacon signal stopped May 10, 1958; beacon transmitted again May 15-June 16; (*b*) first ceased operating May 14, 1958; responded erratically May 22-June 5.	(*a*) Ceased operating Sept. 8, 1958; (*b*) ceased operating Oct. 6, 1958.	
Power supply	Mercury batteries	(*a*) Mercury batteries; (*b*) 6 groups of solar converters.	Mercury batteries	Mercury batteries	Mercury batteries.
Lifetime	Jan. 31, 1958 (3 to 5 years)	Mar. 17, 1958 (200 years)	Mar. 26, 1958–June 27-29, 1958.	July 26, 1958 to—	Feb. 17, 1959 to—.
Perigee (miles)	224	404	118	163	347.
Apogee (miles)	1,573	2,465	1,740	1,373	2,065.
Period (minutes)	114.8	134.29	115.9	110.21	125.85.
Inclination to equator	33.5°	34.25°	33.37°	50.13°	32.86°.
Speed (perigee) miles per hour.	18,400	18,400	18,860	18,406	18,312.
Speed (apogee) miles per hour.	13,700	12,400	13,450	14,232	13,093.

TABLE II(b).—*U.S. IGY space probes*

PIONEER I

Launching:
Date: October 11, 1958, Cape Canaveral.
By: Air Force Ballistic Missile Division.
Vehicle:
Thor-Able 1.
Stages: Four.
First: Thor (liquid).
Second: Modified Vanguard second stage (liquid).
Third: Modified Vanguard third stage (solid).
Fourth: Thiokol (solid).
Total weight, including payload: 112,000 pounds.
Payload:
Shape: Toroidal.
Weight:
Eighty-five pounds (including fourth stage).
Thirty-nine pounds (instrument package).
Experiments: Measurements of radiation in space; magnetic fields of earth and of moon; density of meteoric matter; internal temperatures; electronic scanner.
Velocity:
Designed: 35,250 feet per second.
Attained: 34,400 feet per second.
Altitude: 71,300 statute miles.
Flight result: Reentered atmosphere over South Pacific at 10:46 p.m., e.s.t., October 12, 1958.

PIONEER III

Launching:
Date: December 6, 1958, Cape Canaveral.
By: Army Ballistic Missile Agency and Jet Propulsion Laboratory of California Institute of Technology.
Vehicle:
Juno II.
Stages: Four.
First: Jupiter (liquid).
Second: Eleven clustered Sergeants (solid).
Third: Three clustered Sergeants (solid).
Fourth: One Sergeant (solid).
Total weight, including payload: 121,000 pounds.
Payload:
Shape: Cone-shaped.
Weight: 12.95 pounds (instrument package).
Experiments: Measurement of radiation in space.
Velocity:
Designed: 24,897 miles per hour.
Attained: About 24,000 miles per hour.
Altitude: About 63,000 statute miles.
Flight result: Reentered atmosphere over French Equatorial Africa at 2:51 p.m., e.s.t., December 7, 1958.

Dr. Porter discussed with you in 1958 the status of the satellite tracking program. All Baker-Nunn precision cameras are now in operation, and Smithsonian scientists are engaged in reducing many fine plates obtained by these supercameras. One of the most important achievements thus far of the Baker-Nunn program has been the securing of several good photographs of 1958 Beta, which is, as you know, only some 6½ inches in diameter, and is indeed a very faint and difficult object to photograph. The combination of very good orbit predictions, based on the uniform air drag characteristics of 1958 Beta and the stable orbit, and the advanced photographic technique employed by Smithsonian observers made this accomplishment possible. The orbit of 1958 Beta is known quite well from minitrack observations. The recent optical observations are a very important independent check of the orbit and greatly enhance the scientific value of 1958 Beta.

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Minitrack radio tracking stations, now under the supervision of the National Aeronautics and Space Administration are located at Blossom Point, Md.; Savannah, Ga.; Havana, Cuba; Mont Cotopaxi near Quito, Equador; Lima, Peru; Antogafasta, Chile; and Santiago, Chile. These stations are known as the 75th meridian picket fence. Other stations are located at Coolidge Field, Antigua Island; Bloomfontein, Union of South Africa; Woomera, Australia; and San Diego, Calif.

Baker-Nunn optical observatories are located as follows: White Sands, N. Mex.; near Palm Beach, Fla.; Curacao, Netherland West Indies; Arequipa, Peru; Villa Dolores, Argentina; Olifantsfontein, Union of South Africa; Cadiz, Spain; Shiraz, Iran; Naini Tal, India; Woomera, Australia; Mitaka, Japan; and Haleakala, Hawaii.

II. Scientific Results of the U.S. Rocket Program

Most rocket experiments, while they provide immediate data in the form of telemetered film or magnetic tape records, require months, sometimes years, to evaluate fully the information received on the flights. Rocket instrumentation is very sophisticated and the rocket itself sometimes masks the desired effect so much that great care has to be taken to interpret the telemetered information. Many preliminary findings, however, have been announced by the rocket experimenters. Several symposia were held recently, the latest in Moscow during the course of the Fifth General Assembly of the International Special Committee for the IGY (CSAGI) where scientists of all the nations participating in the program gave papers on their experiments. Following is a summary of recent U.S. results, as presented by the various experimenters at the Moscow symposium and in other recent reports.

Fort Churchill, Canada, was the site of many fundamental new discoveries using rockets. For example, it was found that at 200 km. altitude the atmospheric density in the summer daytime is twice that of the winter daytime; at the same altitude, it was also found that the summer daytime density at Fort Churchill is five times that measured above White Sands, N. Mex. For heights of about 50 km., it was found that the atmospheric density changes by about 2 percent per degree of latitude, a surprisingly high horizontal gradient. Between 30 and 80 kilometers above Fort Churchill, there was found a spread of temperatures of 20° C. between winter and summer. Pressure, density, and temperature measured for most seasons at Fort Churchill in the altitude range between 30 and 90 km. indicate lower values than would be predicted using accepted measurements at lower altitudes. On the other hand, the upper air densities measured with rockets were in good agreement with preliminary densities determined from drag computations on IGY satellites.

Winds were observed above Fort Churchill and found to be very weak and easterly during the summer, while they were westerly and strong during the winter. A peak value of 270 miles per hour was recorded at an altitude of 58 km.

The chemical structure of the atmosphere has also been given attention, particularly to effects of altitude and sunlight. It was found, for example, that diffusive separation of the gases argon and nitrogen becomes effective at about 120 km. altitude, and some diffusive separation was noted between 60 and 90 km. above White Sands. This information is most important to the consideration of the basic physical and thermodynamic behavior of the atmosphere, especially at high altitudes where the density decreases to the point where the classical laws of gas behavior no longer strictly hold, and where the decreasing gravitational field with increased altitude must be taken into account.

The electrical nature of the atmosphere, particularly the distribution of various ionized constituents was given much study. Ionization occurs by the absorption of ultraviolet and X-ray radiation of the sun and also by other agents such as cosmic rays and lower energy particles, and high speed meteors and micrometeors. Nitric oxide, although a very minor neutral constituent of the atmosphere was found to be the predominant positive ion in the E-region of the ionosphere, while atomic oxygen was found to be the predominant positive ion in the F-region. Above Fort Churchill, the only negative ion detected was nitrogen dioxide. This indicates that most of the negative electrical charge, in balance with the positive ions, occurs as free electrons.

The free electron distribution, which is mainly responsible for the ionospheric behavior affecting the reflections and propagation of radio waves, was studied and the electron concentrations measured at various levels during day and

night. Confirmation of many previous ideas was obtained; however, it was determined that in the region between 60 and 80 kilometers, where increased ionization caused by solar disturbances is responsible for radio blackouts, the collision frequency of electrons were found to be lower by a factor of three than previously believed.

Rocket astronomy is a new aspect of the study of radiation from sun and the cosmos, as rockets can carry sensitive spectrographs and other special detectors high above the atmosphere, which shields surface-bound astronomers from many of the interesting parts of the electromagnetic radiation spectrum. Last year, we told you of the important discovery that solar X-ray flashes from flares was the responsible agent for increase in ionization of the low ionosphere, in turn causing radio fadeout. This work was extended to provide unique rocket astronomical observations of the sun during a total eclipse. An extensive expedition was supported by the Navy to carry these rocket scientists, and also a party of conventional astronomers, to Puka Puka, a tiny island in the Pacific. There, the rockets fired in rapid sequence during the several minutes of the eclipse provide important information on the nature of the solar emissions and their distribution on the surface of the sun and in its own atmosphere. A rocket also provided information on ultraviolet emission from far distant diffuse nebulosities. Observations of hydrogen emissions at night have led to some speculations about the distribution of hydrogen in space. It is thought that there is of the order of one-tenth to 1 neutral atom per cubic centimeter, that the distribution about the earth is fairly uniform, and that the kinetic temperature is quite low. These are based on only one experiment and suggest that much more work in this area needs to be done. The recent development of astronomical techniques using rockets may be as great an advance as the recent development of radio astronomy.

Optical phenomena, such as airglow and auroras, were also observed with rocket-borne instrumentation. Important new spectra were obtained of the daytime airglow radiations at altitudes between 60–90 kilometers, and rockets were fired into visible auroras when the ultraviolet radiations from atomic oxygen were observed and a measure was obtained of the energy flux of this radiation. It was also determined that highly energetic electrons were incident on the upper atmosphere in the auroral zone both outside and within visible auroras and it is now thought that electrons rather than protons are the primary source of auroral luminosity and ionization. Electric curents coincident with visible auroras were detected by observatoins of their magnetic fields. The absolute intensities and energy spectra of both electrons and protons in visual auroras were obtained, and extended knowledge was acquired of soft radiation—its latitude distribution, energy, and association with auroral phenomena.

Many rockets carried cosmic ray detectors and it was shown that the latitude knee occurs between 45 and 50 degrees geomagnetic latitude in both the Northern and Southern Hemispheres, and that the intensity of cosmic rays in polar regions was about 60 percent of the value observed during the previous sunspot minimum. Rockets also carried proton-precession magnetometers into the high atmosphere and confirmed the existence of the equatorial electrojet and supplied direct information on its altitude and latitude distribution.

Many important reports of a preliminary nature were published in World Data Center A, Rocket Report Series, No. 1, under the sponsorship of the U.S. National Committee.

III. Results of the U.S. Satellite Program

As table II shows, the United States has placed five satellites into orbit and fired two space probes for the IGY. I have already mentioned the scientific value of 1958-Beta, stemming from the great quantity of good radio and, now, also optical precision observations of its position in orbit. Theoretical scientists of the Naval Research Laboratory carried out an intense program of computation and study of the orbit of 1958-Beta. They have reported new values of the mathematical expression of the earth's asymetrical gravitational field and have recently contributed important new information to the study of the shape of the earth. We hope soon to launch satellites expressly designed for geodetic purposes, but I call to your attention here the results available from work on 1958-Beta as an example of what scientists can do when faced with irrepressible motivation and data somewhat less than ideal.

Dr. Porter reported to you last year on the temperature and micrometeoric studies carried out on 1958-Alpha and 1958-Gamma. I can add little at this time to Dr. Porter's report, except to say that the scientists who took part in these

observations are still working on their data, and even more importantly, have used this preliminary information to assist in the design of new and more complete instrumentation of forthcoming satellites and space probes.

Dr. Porter also mentioned to you the work of our group at the State University of Iowa, and the discovery of the radiation belt around the earth consisting, most probably, of charged particles trapped by the earth's magnetic field. Since that time another satellite and a highly successful space probe have provided information that completely confirms our earlier results and have provided us with a good cross section of the radiation belt, or, as we now know, belts. The data from 1958-Alpha and Gamma allowed us to design and construct detectors for additional work which, we hoped, would further elucidate the nature of the radiation phenomenon. Four specially designed detectors were incorporated in 1958-Epsilon, with various sensitivities and directional characteristics. This equipment was placed into orbit on July 26, 1958, with an orbital inclination of 51°, the maximum inclination which could be obtained from the launching facility at Cape Canaveral with due regard to down-range safety. The increase of inclination over the 34° obtained with the earlier satellites allowed a much better spatial exploration of the radiation effect.

For the entire lifetime of 1958-Epsilon, some 3,600 passes were recorded. Not all the data has yet been read-out and analyzed, but detailed examination of selected passes provided us with a markedly improved knowledge of the altitude, latitude, and longitude dependence of the radiation. It was noted that the contours of constant intensity are bent outwards from the earth at high latitudes, both north and south. The striking similarity of the outer latitude limits of the radiation belt to the latitudes of the auroral zones prompted speculation about the possible relation of the radiation phenomenon and auroral occurrence. On the assumption that the contours of constant radiation intensity resemble the shape of the magnetic field lines, figure 1 shows our speculation of the radiation distribution based on data from 1958-Epsilon. Later data from the Pioneer I space probe tended to confirm this picture but data from Pioneer I were not reliable enough to advance our knowledge much beyond this point. Figure 2 shows how charged particles could, trapped by the earth's magnetic field, circulate from the north to south polar region in the radiation belt.

There were members of our group who debated the speculation depicted in fig. 1, and who made alternative speculations. We had the opportunity to further our knowledge when Pioneer III was successfully launched from Cape Canaveral on December 6, 1958, and provided us with data to a distance of 66,500 miles from the earth. Two Geiger-Mueller counters were used as detectors. Excellent telemetry provided continuous radiation observations on the out-bound leg of the trajectory to a distance almost to apogee, and from about 37,000 miles to 5,800 miles on the return trajectory. These observations showed that there were not one but two distinct peaks of intensity. Based on this important set of observations we have constructed a new speculation, this time with considerably more confidence, of the structure of the radiation belts, shown in fig. 3. The heavy black dots show specific points through which the contours were drawn; there is still, however, much speculation in this diagram.

It appears that the outer zone is the one probably more intimately related to usual, high latitude auroras. It will not be at all surprising if the intensity level of the trapped radiation, and indeed the structure of the entire region, are found to be strongly dependent on solar activity averaged over some mean trapping time of several weeks or months. Gross fluctuations over the 11-year solar cycle may be expected, and there probably will be found fluctuations of a much shorter time scale.

It is too early yet to put forth with any confidence speculations on the detailed nature and source of the trapped radiations. There may be different sources for the two zones, and several possibilities have been proposed lately by many scientists. We need to explore further the range of energies of the particles, and indeed their identities, i.e., whether electrons, protons, or both. Pole-to-pole orbital or vertical probes in the plane of the geomagnetic equator will help complete our knowledge of the structure.

There appears to be no sharp cutoff of the trapped radiation, but the observations lead us to believe that the outer limit to the trapping is about 10 earth radii, at which distance, at least as measured with the present equipment, the trapped radiation becomes less intense than interplanetary cosmic-ray radiation.

The counting rate showed only statistical fluctuations beyond 10 earth radii. This appears to mean either that no "blobs" of interplanetary plasma, as discussed last year with you by Dr. Simpson, were encountered during this observing period, or that any such blobs as might have been encountered did not contain sufficiently energetic radiation to produce significant contribution to the counting rate. The experiment took place during a time of only mild to moderate solar activity.

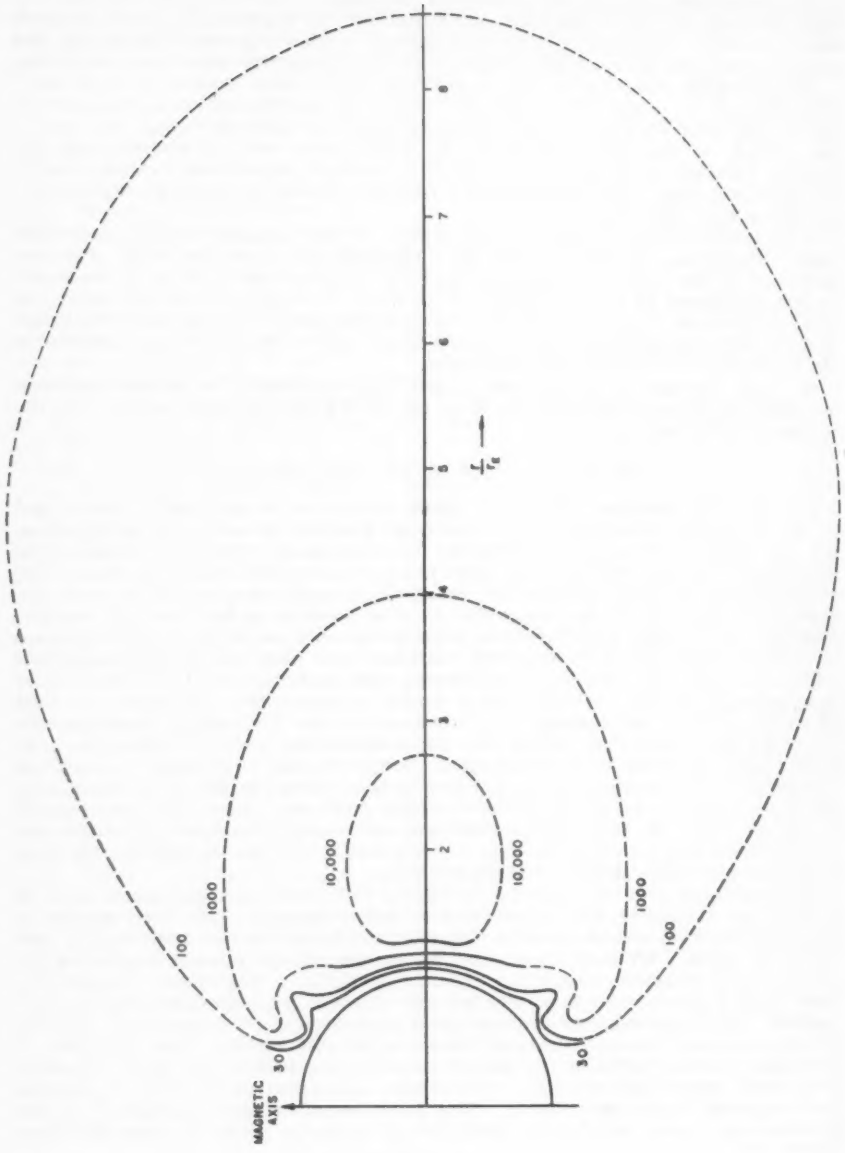
With indefinite knowledge of the identity of the trapped particles and their energy spectrum, we can only estimate the biological exposure level. We suggest that if the detector's response was due to electrons or X-rays, the levels in the maximum of the two zones is between 5 to 10 roentgens per hour; if, however, protons are the agent, then the biological exposure may be in the range of 50 to 200 roentgens per hour. It is still not known, however, how absorbable the radiation is at various points of space.

We have calculated the number of particles that might be trapped and suggest that as little as one-fifteenth of an ounce of hydrogen could account for the entire radiation belt.

IV. Implications of the IGY Program

For the IGY program, almost as many rockets were launched as were used in the 10 years preceding. This enormous increase in scientific information, not only from sheer numbers alone, but from increased experience and scientific "know-how" in this difficult technique, has pushed rapidly ahead our knowledge of the upper atmosphere and has resulted in many new and important discoveries. Satellites do not take the place of rockets, rather they are complementary, and rocket experimenters hope to be able to keep up with the pace of research established by the IGY. Rockets will also play a most important role in proving our new instrumentation ultimately intended for satellite or deep space-probe use. We have good reason to believe that the facility at Fort Churchill will be maintained as a research facility for rocket experimenters, and with the advent of newer and easier-to-handle rocket systems, we may expect more facilities to be established. Much remains to be done in extension of coverage; for example, we should like to have firings in the Antarctic during the winter night and in the interior of the continent. The U.S. Army Signal Corps and the U.S. Weather Bureau are now on the threshold of routine use of meteorological sounding rockets to supplement the use of balloons for data in the altitude range of 100,000 to 200,000 feet.

The importance of the elucidation of the radiation belts has many aspects. Cosmic ray scientists, for example, now must redesign their instruments so that they will be either shielded from or unaffected by the radiation in this region of space. We now know that we cannot expose nuclear emulsions for the detection of heavy cosmic ray primary particles in this region of space; we must work below or above, or else demand satellite or probe orbits in the polar regions. The knowledge of the biological exposures is most important to know in planning any manned vehicles operating in this region. The discovery of this phenomenon, furthermore, has given us a new hold on the study of solar-terrestrial effects and promises to stimulate new creative thinking on auroral and magnetic storm phenomena. The detection of trapped particles has also provided us a new tool for the detection of magnetic fields of other planetary bodies.


8
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30
30
MAGNETIC AXIS

FIGURE 1

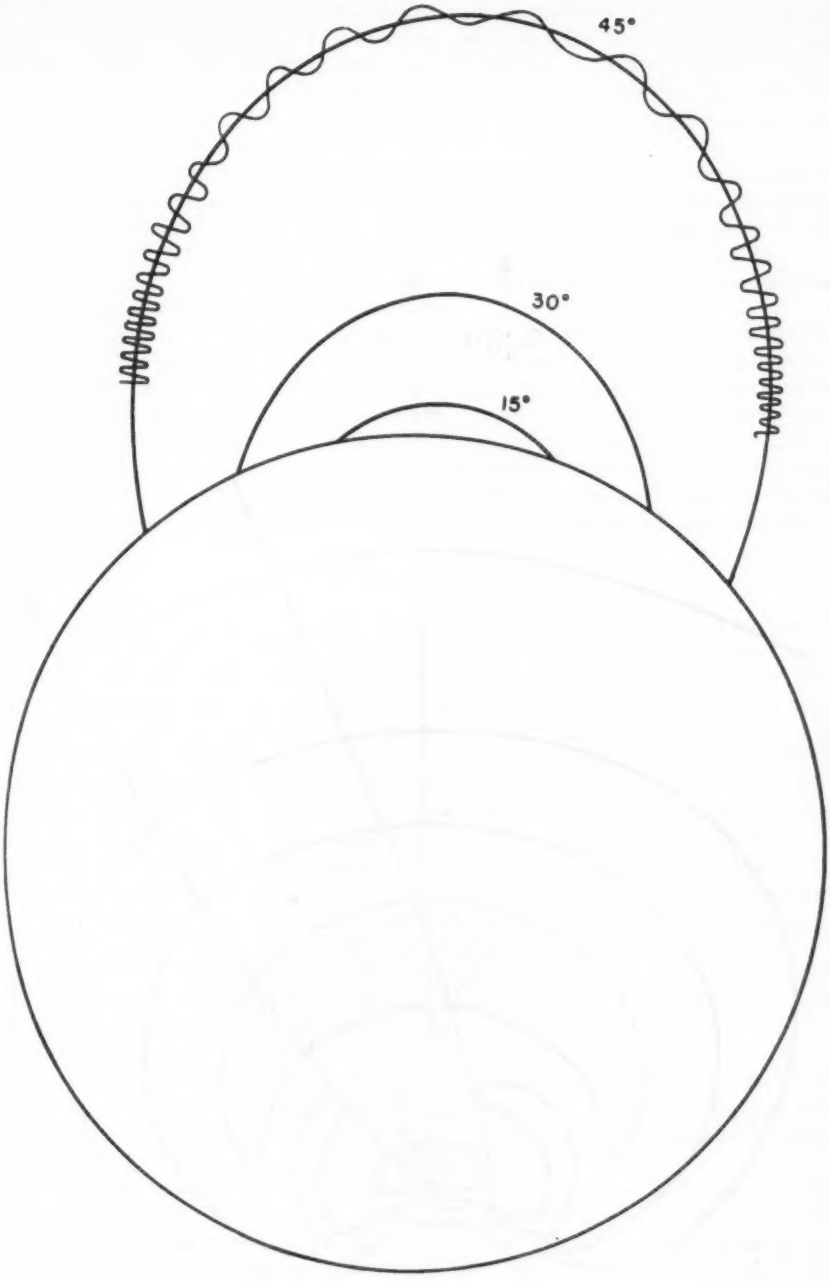

FIGURE 2

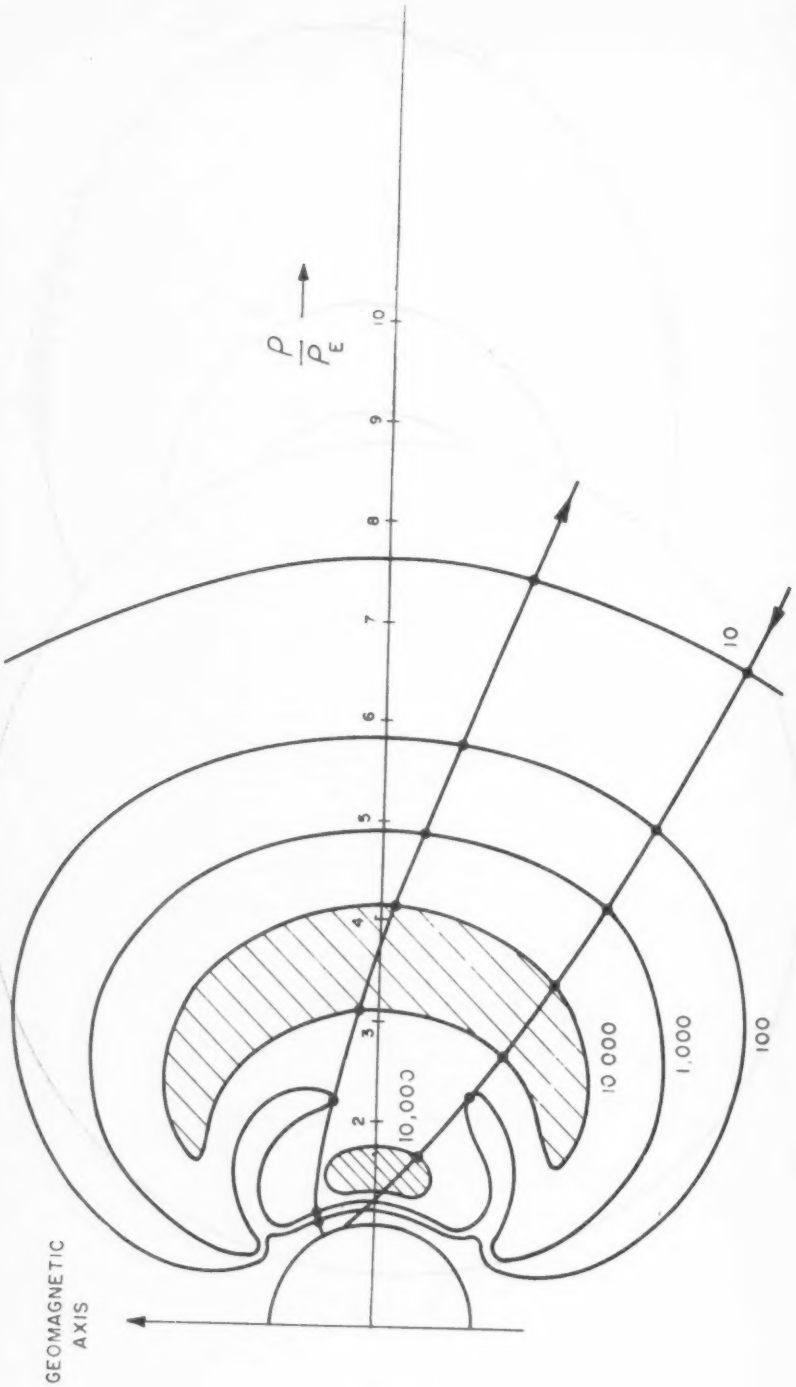

FIGURE 3

Dr. VAN ALLEN. Mr. Chairman and gentlemen, I had the great pleasure of being here 2 years ago before this committee, but unfortunately I had to miss last year's session. The reason is that I was working at that time and we just had one satellite up and we were busy trying to decide its meaning. Now I am happy to say we can report on what it did mean.

Two years ago the burden of our presentation here was in the nature of plans and intentions and I have always been very uneasy about talking publicly about what we propose to do, but this year I am happy to say that we do have some solid achievement to report.

If I may, I would like to first make two remarks of a more peripheral nature, perhaps more of a human nature.

During World War II, I had the very good fortune to work for Dr. Tuve, who spoke this morning, and I would like to say that when our ways parted after the war I felt that the great loss in unity and vitality of purpose which I suffered then was renewed during the IGY. I believe there is nothing like it for human endeavor in this country in the way of a unified, vital earth since the war. During the war, our purpose was basically a grim one and now we have a very beautiful set of peaceful objectives and peaceful achievements.

STIMULUS OF IGY

The other remark I should like to make is that in this business I have been working with young people in the universities and high schools nearby, and I think it would be fair to remark that nothing has stimulated the interest of the young people in the measure that the IGY activities have. I see this every day. In fact, we are astonishingly enough now snowed under by young fellows interested in studying physics. As you probably well know, and I am sure Dr. Kaplan agrees, this is a rather revolutionary development in the world. I personally feel that this sort of thing vastly transcends any of the more artificial means of stimulating interest in education. Now we really have something to live for, so to speak, in our science.

Mr. THOMAS. Let me interrupt you a moment. You even stimulated that interest in me. I go out to your wonderful institution two or three times a year, but every time I go out, you are so far away from where I am that they tell me that I should not stimulate that interest too far in the work over there.

When you go back, tell Dr. Flauss hello for us.

Dr. VAN ALLEN. I think that you should realize that most of us show up here in clean-shaven condition but that we spend most of our time sweating, straining, and swearing, trying to get some of these things done that I am going to speak about.

I have found it illuminating, if you will permit a somewhat light comment, to think of science as a huge, lumbering animal. Most of the time he just goes waddling and lumbering along and picking at tufts of grass and nosing around in the dirt, but once in a while he takes off in a real burst of speed. I think we can report that this animal of ours has had a few bursts of speed during the IGY.

At the present time a good many of us are what we might call laying down and ruminating. We are trying to decide what we have found out and understand it and relate it to other phenomena of

significance in the whole picture. My report is basically what I might call a report from the Gun Club, if I may use Jules Verne's term.

You may recall the Gun Club as enthusiastic volunteer scientists in Baltimore some 100 years ago planned and carried out two trip-to-the-moon flights.

We have a modern day Gun Club of which I am a member, so I am essentially reporting for the club today.

Two of the powerful new tools which geophysics has, which they did not have during the previous years, are rockets and satellites. Both of these have a very unique function in geophysics and neither one supplants the other. We fully expect that both rockets of the vertically fired, short-duration variety, and the long-term satellites will continue to exist side by side as very useful techniques in studying what is going on in our general vicinity. During the IGY the sum total of our Gun Club had some 200 rocket flights ranging from locations off the coast of northern Greenland to the Ross Sea and Antarctic. Not all of these were successful. We poked a lot of holes in the atmosphere and in at least half of these we attained some quite beautiful results.

I have a prepared statement which I have submitted for the record which was prepared with the help of Mr. Odishaw's excellent staff. They helped me out with my homework on this, but I would like to describe some of what I consider the main dashes that waddling animal of ours has been making.

ROCKET RESULTS—AURORAL OBSERVATION

In the first place, we have succeeded for the first time in history in shooting a number of rockets right through visible aurora. These great phenomena which Mr. Shapley has described so beautifully occur commonly at latitudes such as that of Fort Churchill where we had a rocket based during the IGY for the first time. From this base, we have managed to shoot about 10 rockets right into visible aurora and have observed for the first time in history what it is that is in an aurora by direct observation. In other words, we are looking right into the throat of an aurora and measuring what is actually there by observations with fairly elaborate instruments placed where it is happening.

Mr. THOMAS. What altitudes have you reached?

Dr. VAN ALLEN. About 60 to 100 miles altitude.

X-RAY OBSERVATIONS

Secondly, there has been some very beautiful work done on the X-ray emission from the sun which is a field of very great interest and one which Dr. Roberts has referred to, and again for the first time, by means of rockets, Dr. Friedman and his associates have measured the direct reception of soft radiation equipment on rockets well above the absorbing atmosphere. These X-rays are ordinarily absorbed in the high atmosphere and are not accessible to observation from any ground or balloon station.

At the same time they are being absorbed, they produce great physical changes in the atmosphere. They disrupt communications. They cause absorption of radio noise from outer stars and likely have many important other side effects of a geophysical nature.

One of the special achievements of this group of workers was in measuring, during a solar eclipse this past fall, the X-rays from the sun when it was occulted by the moon. They found, among other things, that most of the X-rays originate in the very outer fringes of the sun's corona and continue to come into the earth even though the face of the sun is so completely occulted by the moon.

MAGNETIC OBSERVATION

The third achievement with rockets has been the plotting by direct rocket observations of electrical current flowing in the atmosphere. Dr. Revelle mentioned this morning the rivers of water moving in the ocean. We have an analogous situation in the high atmosphere, except that these rivers are electrical rivers. They are huge flows of current and by means of small rockets fired in the central Pacific during the fall of 1957 a young graduate student of mine, Lawrence Cahill, succeeded in poking four different rockets through this great electrojet, so-called, into the equatorial region and measured the structure of this current.

He found, as have the oceanographers, that there is also a reverse current flowing there which was not previously anticipated.

Mr. THOMAS. Quite an accomplishment.

Dr. VAN ALLEN. Let me now turn to a few remarks about satellites.

SATELLITE PROGRAM

As you know, we have had, by the United States during the IGY, four successful satellites, and as of yesterday we are pleased to welcome aboard one new one. I might say that my prepared remarks are 1 day out of date. They do not contain a description of this flight.

Mr. THOMAS. Will you please revise and extend your remarks to bring that statement up to date.

RADIATION BELT

Dr. VAN ALLEN. I might say that this great event of February 10, 1959, which had been mentioned, was observed by our satellite equipment. This was a matter of pure chance. Our Explorer I was launched on the 31st of January 1958 and was operating and doing beautifully during the period of this great aurora. I am very pleased to say now we have quite a beautiful set of measurements describing what happens in the lower regions of the radiation belt during this occasion.

There were great things going on in the very, very high reaches of the atmosphere during this occasion that we passed right through a number of times and observed directly. I think one of the most interesting findings of the satellites work of the United States has been the discovery of what appears to be a genuinely major phenomena of nature; namely, that in the outer reaches of the earth's magnetic field, there is confined a great body of hot plasma, or ionized gas, semipermanently confined in this region, and of very great intensity. In fact, the intensity is so great that it would take some billions of X-ray machines to manufacture the same equilibrium, volume, and intensity

that we observed to be present. This was an example of the beautiful word I have recently known as serendipity, meaning to find pleasant things without having anticipated them.

You may recall there were two instances of serendipity in this fine tale of Horace Walpole.

That is, where he is going around the country and always coming across some very pleasant incident he had no reason to expect.

This is characterized in the IGY work and it certainly characterized the satellite work. I must say that one must be going someplace in order to have these things happen to him though. I think that is characteristic of science where this often happens.

Mr. THOMAS. You just planned it that way, Doctor. Do not be so modest.

Dr. VAN ALLEN. I could not claim that.

Mr. RHODES. Would you characterize that great belt of radiation as a pleasant thing to happen to you?

Dr. VAN ALLEN. From a scientific point of view.

Mr. RHODES. It titilates the imagination!

Dr. VAN ALLEN. Yes.

However, I must say we first discovered this with Explorer I, but we were very reluctant to believe it and, in fact, at the time of the committee hearings last year—I was not present last year—the main reason was that we were trying to make sense of what we had at that time. However, it was confirmed with a quite different apparatus with Explorer III and Explorer IV fired last July. We have a beautifully complete and rather elaborate set of observations confirming the earlier observations in full and greatly extending them and giving us a much richer understanding than we have ever had before.

In addition to that, we have had two so-called space probes. These were originally known as lunar probes, but have now been renamed space probes for fairly obvious reasons.

We will have another one in the near future. All five of these flights have confirmed the existence of this great phenomena and have now given us a rather—not a full—but a rather good idea of what is going on.

We believe that this is a phenomena that is, so to speak, complementary to some of the things that Dr. Roberts sees happening on the sun.

In other words, he manages the sun and starts all of this and we catch it all here, so to speak, where it ends up on earth. At the present time we have geophysical theorists all over the country and I think more or less all over the world, busy trying to account for this detail, as to how this comes about. At any rate, we are trying to keep busy and my main job might be called an observationalist or experimentalist. We are trying to find out what is going on and trying to understand it and get all the help that we can in fully understanding it.

I might say that a very pleasant feature of this has been that the Soviet Sputnik III rocket fired last May 15 has confirmed in full our observations to the best of our understanding of what they have reported so far. There is a complete coherence of observation. It appears to us at least that we do have a good deal more detail and fuller understanding than they do, so far, but this may be due to the delay in the pipeline which has not reached us yet.

It does appear that our results have profited by what we believe to be a considerably superior observing network. We had a beautiful array of stations during the flight of Explorer IV in July, August, and September 1958. We had in operation over 30 radiotelemeter stations splattered around the world in a quite full network.

As a result of that, we have a total of 3,600 observed passes of this satellite during its two months of battery life.

There seems to be no comparable network of observations evident in any of the Soviet announcements so far.

IMPLICATION OF RADIATION BELT

I would like to say that we feel that this great radiation belt is going to be of immense interest in the tying together of a large body of geophysical observations. The most immediate and intimate relationship is likely with the aurora, with the northern and southern lights, and we have the following working hypotheses; that the radiation belt is a great reservoir of high energy charged particles which are occasionally perturbed and, so to speak, leak down into the atmosphere when fresh batches of solar gas arise. We like to think of it as a great bowl of jelly which is occasionally perturbed and which shakes some off the edge down to the world zone and makes an aurora. At the same time, we believe that the great reservoir of radiation contributes to, and may be the direct cause of so-called magnetic storms.

This sort of thing Mr. Shapley just showed, the great perturbations in the magnetic field of the earth and the accompanying effects of other types.

Furthermore, it does appear that there is enough leakage out of this reservoir to contribute significant and perhaps important heating to the very thin upper atmosphere. As a general idea, we think that this trapped radiation is stolen from beams of gas, blobs of gas shot out from the sun. Those blobs which Dr. Roberts sees flying out from the sun go out without reference to the earth, but occasionally one may pass close to the earth and elbow it way into our magnetic field and continually replenish and store up radiation in our vicinity. That is a working picture. It may be wrong but that is our working picture, at any rate.

Finally, I would like to mention an event which is again serendipitous.

ARTIFICIAL AURORA

As has been publicly announced there were two high-altitude atomic blasts conducted in the Pacific near Johnston Island on the 1st and 12th of August 1958. Within a minute after the first blast a very alert New Zealander in Samoa observed a remarkable visible aurora from Samoa for the first time in history; namely, a low-altitude aurora. After that he made some beautiful visual records on observations. He later read in the newspapers that people in Hawaii had been aroused by a brilliant flash of light in a certain time in the day, about 1 minute before he observed the aurora, and connected these two and surmised that this was indeed the first man-made aurora in history; namely, the first time by human effort a visible aurora had been produced in the upper atmosphere. There were also observed at Samoa and at other magnetic observatories in the Pacific a

magnetic storm unique in character and, by its time association, almost certainly a side feature of these atomic blasts. These effects were observed in connection with both the August 1 and August 12 events.

I think this has a vast significance in terms of future possibilities for studying geophysics; namely, making one's own aurora whenever he feels like it and wherever he feels like it and studying the associated effects. Many of the mysteries of magnetic storms will be, or can be, illuminated by artificial geophysics.

Another major effect is that both the McKay Worldwide Radio Network and RCA Network experienced complete blackouts of radio communications on their transpacific circuits and rushed around for about a day trying to find out alternative means for trying to deliver messages across the Pacific and to Hawaii.

Mr. THOMAS. At the same time the artificial aurora went off?

Dr. VAN ALLEN. Yes, sir. It started immediately and persisted.

Mr. THOMAS. You must have a point there. Go ahead.

Dr. VAN ALLEN. It started immediately and persisted for about a day and a half. I might also remark, if I may go off the record, something else in that connection of interest which happened.

(Discussion off the record.)

Dr. VAN ALLEN. This is the only artificial geophysical event of this scale ever produced and it is one of very great interest. We are busily engaged now in trying to understand and interpret all of these associated effects. I think that is perhaps all I intended to say, but I have one remark, due to my good friend, Dr. Hartline, that I thought might be of some amusement to indicate the scale of our ignorance in many matters in outer space.

As you know, a good deal of discussion is going on as to what we are going to do when we get to Mars, for example. One of the keenest groups of persons are those who would like to find out if there is life on Mars. It has been variously proposed that some kind of a miniature scoop shovel be dropped on the surface and pick up something and examine it and see if there is any living matter in this scoop shovel. Dr. Hartline suggested this, but he also remarked that while this miniature scoop shovel is at work, it may very well be trampled on by a herd of Martian elephants.

That illustrates the scale of our ignorance.

Mr. THOMAS. That is a great statement and we certainly enjoyed it.

SATELLITE OBSERVING STATIONS

Did I understand you to say a while ago, Dr. Van Allen, we had 130 monitoring stations?

Dr. VAN ALLEN. No; we had over 30. That was regularly organized stations in this work.

Mr. THOMAS. Were they IGY stations or ours?

Dr. VAN ALLEN. They were IGY stations; yes, sir.

Mr. THOMAS. They were useful not only to us in our efforts with the satellites, but to the Russians as well; were they not?

Dr. VAN ALLEN. Yes, sir.

Mr. THOMAS. Perhaps I misunderstood you. Did I understand you to say that we did a better job of monitoring our satellites than the Russians did theirs?

Dr. VAN ALLEN. Let me see if I can clarify this. These 30 stations were set up specifically to work with our satellites. They were located in about 20 different countries with the cooperation of local persons in each of these countries. As you probably recall, the codes and frequencies of sputnik transmissions were not generally known in advance and most of these stations were not prepared to receive Soviet signals.

Mr. THOMAS. I understand; but they were ours, and we set them up for everybody.

Just one other interruption.

Did I understand you to say that we took some photographs of the upper atmosphere in the area where the aurora was and we got some valuable information with reference to radiation particles and so forth, and with reference to time? When was the picture made? With reference to the aurora, itself, and then with reference to the explosion? In other words, how long did those particles stick around in the area?

Dr. VAN ALLEN. The visible aurora was observed for about 6 minutes by this New Zealander in Samoa. We detected it with our satellite for many hours.

Mr. THOMAS. It was all in the same area?

Dr. VAN ALLEN. Yes, sir.

Mr. THOMAS. Did you find any particularly useful information in the particles? Were you able to discover something in the particles themselves?

Dr. VAN ALLEN. Yes, sir. We have a rather good idea of what the particles were and their energy distributions and distribution in space.

Mr. THOMAS. Did you get any idea of the length of time that the particles would stick around with reference to their density, intensity, and so forth?

Dr. VAN ALLEN. Yes, sir.

However, I should like to ask that this part be off the record.

(Discussion off the record.)

Mr. THOMAS. We are making progress and this has certainly been very interesting.

RECEPTION OF SATELLITE TRANSMISSION

Mr. YATES. You indicated in your earlier answer to Mr. Thomas—of course, we knew this from 2 years ago—that the wavelengths or transmission signals of the sputniks were of a type we were not geared to receive.

Was this true only of Sputnik I or was this true, as well, for succeeding sputniks?

Dr. VAN ALLEN. It was most notably true for Sputnik I. They used the same on I, II, and III, though they did not tell us in advance, although it turned out that they used the same on II and III. We were in a much better state of preparation for those than the first.

Mr. YATES. You were able to receive the signals?

Dr. VAN ALLEN. We were able to receive Sputnik I after 1 day. In fact, I was floating around in an icebreaker in the Pacific when it was fired; we got the radioman out of bed and we got on it right away. We were receiving it on the U.S.S. *Glacier* 2 hours after it was fired, by strictly jury-rigged means.

Mr. YATES. The second question relates to the Vanguard that was fired yesterday. I understand that the rocket was propelled by solid fuel?

Dr. VAN ALLEN. No; the third stage is solid fuel. The first two are liquid.

Mr. YATES. The question has been asked of me, why the rocketry people have used liquid fuel at all, rather than solid fuel?

Dr. VAN ALLEN. It is a detailed engineering question. The liquid fuel at the present time gives a much better so-called mass ratio of total mass to inert mass, and it is much better for a rocket in the present state of technology. For the same mass of rocket, you can put up a much heavier payload with liquid fuel at the present time. I do not know if that will always be so.

Mr. YATES. You have had so much difficulty with using them, but you do not have the difficulty with the solid fuels?

Dr. VAN ALLEN. We have had different difficulties. The solid fuel is not all clover.

Mr. THOMAS. Not all peaches and cream by any means.

Dr. VAN ALLEN. A good many solid fuels rockets blow up and do other weird things as well. There are fewer working parts in a solid fuel rocket. That does not necessarily mean that it is more reliable, although large, solid fuel rockets do not yet exist to that scale.

Mr. JONAS. Would you yield?

Mr. YATES. Yes.

Mr. JONAS. Does that same principle apply to missiles as well?

Dr. VAN ALLEN. Yes, sir.

Mr. BOLAND. Would you say that the satellites that we put up are more sophisticated instruments than those the Russians put up? In the long run, do we get more information from our small satellites or have we, to your knowledge, maintained and gotten more information from those we have put in the air than they have from theirs?

Dr. VAN ALLEN. I must say that I do not yield to the Russians in ideas and scientific competence as far as this country is concerned. There is no doubt they have a vastly superior vehicular system.

Mr. THOMAS. Power. They have more power than we do.

Dr. VAN ALLEN. They have succeeded in developing a larger rocket engine.

Mr. BOLAND. I am talking about the ultimate instrument in the air. Is that true, or is our instrument more sophisticated? Do we get more information from that final instrument than they do from theirs or is ours a better one in the final satellite stage?

Dr. VAN ALLEN. I think I understand your question.

I would not say so. I think they have done some beautiful experiments in their satellites in their one unique space probe so far. In fact, they have done exactly almost the experiments we would like to do, but have not been able to manage.

Mr. BOLAND. I am glad to hear it but this has been my apology for some of our failures.

Mr. THOMAS. We are getting this right from the horse's mouth, gentlemen.

Mr. YATES. At the time Sputnik III was fired, Dr. Porter mentioned he was amazed by the instrumentation Sputnik III contained.

Mr. THOMAS. When you are able to have the horsepower to put up a ton and a half, you will have a lot of instruments in there, too, will you not?

Dr. VAN ALLEN. Yes. I would say that per pound we learned a lot more science, but I think a miniaturization——

Mr. YATES. You do not mean to say we are lightweights?

Dr. VAN ALLEN. No.

Mr. BOLAND. Are you getting as much information or more from what you are putting up than they are getting from the tremendous things they are putting up?

Dr. VAN ALLEN. No.

Mr. THOMAS. Not per pound, but per total quantity you are not.

EXCHANGE OF INFORMATION

Mr. JONAS. Doctor, may I direct this question to you, or perhaps all of the gentlemen who have been in Russia in the last year:

Have any of our scientists who have been in Russia been permitted to go anywhere near their launching sites? Do we know where they are?

Dr. VAN ALLEN. I think the answer is a definite negative.

Mr. JONAS. To the second question, too?

Dr. VAN ALLEN. Negative to both. We have a good idea where the sites are by tracking the rockets.

Mr. JONAS. At least they do not publish the location of their sites.

What has been the extent of your conversations with your counterparts in Russia about satellites?

Dr. VAN ALLEN. My own have been limited mainly to an IGY meeting in Barcelona, 2 years ago.

Mr. JONAS. I mean since then.

Mr. THOMAS. Dr. Kaplan was just there and Dr. Berkner and half a dozen of you gentlemen here.

Mr. JONAS. I would like to hear somebody discuss that briefly.

Dr. KAPLAN. Mr. Shapley was there. Mr. Odishaw was there, and Dr. Roberts.

Mr. JONAS. How far did they go with you gentlemen in discussing their techniques?

Dr. SHAPLEY. There was a fairly quite full discussion of the results of the experiments. There was a rocket and satellite symposium at Moscow last fall organized by Dr. Berkner although he was not there himself, on the scientific results and there was a lot of information given. As for instruments, I know that I saw the prototype or copy-magnetometer.

Mr. JONAS. Did they have exhibits or display models?

Dr. SHAPLEY. Yes, sir.

Mr. JONAS. Instrumentation?

Dr. SHAPLEY. In the Industrial and Agricultural Exhibition in Moscow they had a full-sized model of Sputnik III and at least some of the instruments in it. As I say, I actually held in my hand and examined a carbon copy of their magnetometer at one of their labs outside of Moscow where I visited. I believe that Dr. Simpson has one

of the cosmic ray Geiger counters that was in Sputnik I. The story he tells is that he did not get it from a Russian scientist but saw it in a window of a shop in Leningrad and went in and bought it.

By and large, it seems as if many of the instruments put into Russian satellites are rather ordinary, still good, but ordinary laboratory instruments that are mounted in the satellite.

Mr. JONAS. Have we learned anything from looking at their models? How do they compare with ours?

Dr. SHAPLEY. I can only speak for the magnetic instrument but I am told it was a very, very good instrument.

Mr. JONAS. Do they follow the same principles that we follow?

Dr. SHAPLEY. The same principles; yes.

VEHICLES FOR LAUNCHING SATELLITES

Mr. RHODES. I would like to ask Dr. Van Allen why have you not used an Atlas for a space probe or a lunar probe? You mentioned the fact that you do not have the power and it seems to me that you have not used the vehicles which we have available with the most power. The Thor-Able has not been used and the Atlas, as far as I know, was only used once and that was to put up the last Explorer.

Dr. VAN ALLEN. The Thor-Able was used for Pioneer I and II tries with moderate success. Those are primarily military vehicles and developed for military use. After the military we come next so we have had no opportunity to use them so far. We are very eagerly looking over their shoulders for the earliest opportunity to use a larger vehicle.

Mr. RHODES. You mentioned that the Russians had a vehicle available which was greatly in excess of the power of ours.

Did you mean by "ours" yours, or did you mean any vehicle which we have in our defense set-up?

Dr. VAN ALLEN. The vehicle which put the Russian moon rocket into orbit around the sun has a considerably greater thrust engine than anything we have in sight in this country under any auspices.

Mr. RHODES. Do you have any idea or do you know what kind of a vehicle it was, liquid-powered or solid-fuel?

Dr. VAN ALLEN. I believe we do not, but it is a very reasonable presumption that it was a liquid fuel rocket, based on our knowledge in this country.

Mr. YATES. Could it have been nuclear fuel?

Dr. VAN ALLEN. I do not believe so.

Mr. RHODES. Actually, there would not be any great trick in developing a big one, bigger than the one we have now, if you used the same kind of fuel. It is just a matter of mass; is it not?

Dr. VAN ALLEN. There are many complications. As soon as one doubles the diameter of a rocket engine, he has a vast new set of problems. In other words, in a nutshell, they do not scale. You cannot simply double them and you have a whole new variety of problems.

Mr. THOMAS. Dr. Kaplan?

Dr. KAPLAN. Thank you, Mr. Thomas.

Statement of Dr. Lloyd V. Berkner Concerning Continuing the Space Program

Dr. Berkner is the last speaker, but after Dr. Berkner, if you allow, I would like to enlarge a little bit on my own testimony.

Mr. Thomas. You have been sort of neglecting us, Doctor. The last time you were here, you walked out with $20 million for a brand new laboratory. That is another one of his many new activities. He has an activity in New York, one all over the world, in this regard, and now he has gone into a third one in West Virginia.

We are delighted and honored to welcome you back home.

Are you planning to go to the South Pole any time soon, Doctor?

Dr. Berkner. I am just back.

Mr. Thomas. That is, between your various activities?

You are a man of many, many capabilities, Doctor.

We are delighted to have you and will you please talk to us?

(Dr. Berkner's prepared statement follows:)

THE CONTINUING SPACE PROGRAM

Mr. Chairman and members of the committee, it is an honor to be here today to discuss with you the legacy which the IGY leaves with us in the field of space research.

Perhaps this is the area of the IGY's greatest impact. For it was the IGY mechanism, established by the world scientific community through the International Council of Scientific Unions, which stimulated the first steps forward into space within the context of a peaceful, international program. A vast new frontier has been opened to the energies of man, and his intellectual horizons have expanded commensurately.

The importance of these first steps into space do not need to be emphasized. The remarkable discoveries already described to you by Dr. Van Allen are without question only the forerunners of even more remarkable findings to come. It is certain that new knowledge will be gained, of great importance not only for expanded activities in space but also for the understanding of problems in the physical and life sciences on earth.

I should say that this great international program was not conducted without benefit to the national interest. American scientists were greatly stimulated to devote time and energy to a much-neglected area. Their progress has been greatly speeded up. Moreover, they have gained insights into the techniques and capacities of other participating nations which would not otherwise have been available. Not least, this Nation's interests and those of all other nations were served by the direction of space activities into peaceful channels.

It is evident that the progress of scientific investigations in space depends upon providing the broadest possible support by the scientific community. For, the spectrum of scientific interests in space is very broad; it includes investigations of gravitational and magnetic fields, the composition and processes of the interplanetary medium, life processes in space and on other planets, the nature of the atmospheres and ionospheres of other planetary bodies, the composition and structure of such bodies, astronomy, solar-nuclear processes, and many other fields. This means that intelligent investigation of space requires constructive contributions drawn from the entire scientific community, including government and private agencies and laboratories, and especially the universities. No single segment of our scientific society can hope to make available the necessary resources in brains and training for this enormous effort.

INTERNATIONAL COMMITTEE FOR SPACE SCIENCE

These considerations apply both to national and international programs. On the international level, the International Council of Scientific Unions, which sponsored and organized IGY internationally, recognized very early that the

degree of success achieved in the IGY satellite program made it most desirable that international sponsorship of similar efforts be continued by the scientific community.

ICSU's objective was to stimulate scientists everywhere to provide the necessary broad support in theory, research, and experimentation in the pattern that proved so successful during the IGY.

Accordingly, at its eighth general assembly in Washington last October, the ICSU established a Committee on Space Research (COSPAR). The stated purpose of COSPAR is to provide the world scientific community with means by which to exploit the possibilities of satellites and space probes for scientific purposes and to exchange the resulting data on a cooperative basis. ICSU recognized that there might be interest in regulating activities in this field. Accordingly, it instructed COSPAR to keep informed of UN and other pertinent activities in order to assure a reasonable regulatory framework in which to conduct space research.

COSPAR's membership includes:

(i) A representative of the scientific institutions of each of the countries actively launching earth satellites, as well as of those countries having major programs in rocketry. At the present time, these members represent institutions in the United States, Soviet Russia, the United Kingdom, Canada, Australia, France, and Japan.

(ii) Representatives, on a rotating basis, from countries actively participating in tracking and other aspects of space research. The three members selected for the first year were Peru, South Africa, and India.

(iii) Representatives from each of nine specified international scientific unions: International Astronomical Union, International Union of Geodesy and Geophysics, International Union of Pure and Applied Chemistry, International Scientific Radio Union, International Union of Pure and Applied Physics, International Union of Biological Sciences, International Union of Theoretical and Applied Mechanics, International Union of Physiological Sciences, and International Union of Biochemistry.

The first meeting of COSPAR was held in London, November 14 and 15, 1958, for the purpose of organizing the Committee. (See attachment A for report of first meeting, membership, charter, and rules.) Dr. Homer E. Newell, Jr., now Assistant Director for Space Sciences, NASA, was designated Convenor by ICSU. Procedural rules were framed and officials elected. The President of COSPAR is Prof. H. C. van de Hulst, a distinguished radio astronomer from Holland, representing the IAU. Two vice presidents were elected, Prof. E. K. Federov, representing the Soviet Academy of Sciences, and Prof. W. A. Noyes, Jr., representing the National Academy of Sciences of the United States of America. The vice presidents alternate precedence every 3 months and are required to provide for election of a new president if that office is vacated for any reason. These 3 officers, together with Prof. Maurice Roy, the delegate from IUTAM, and Prof. H. S. W. Massey, the delegate from IUPAP, constitute the executive committee of COSPAR. (The executive committee is limited to 5 members who must include representatives of the satellite-launching nations.)

COSPAR has been installed in The Hague with the ICSU secretariat. It is planned that support will be by subvention from each of the participating national academies. The United States and the USSR have each been asked to contribute $15,000 for the first year; the other participating nations have been asked for $5,000 each, making a total of $55,000.

The Soviet Union's national academy participated in the first meeting of COSPAR and gave approval at that time to the charter as drafted. Its representatives were Academicians Sedov, who first announced the Soviet IGY satellite program, and Blagonravov, who is prominent in the Soviet rocketry program and was leader of the Soviet delegation to the IGY Conference on Rockets and Satellites at Washington in 1957. Academician Federov will be official delegate. The caliber of these representatives suggests the level of Soviet interest.

As its charter indicates, COSPAR is not concerned with the technology of rocketry, with launchings or with launching vehicles. It is concerned with scientific experiments, on-board and ground-based, which may be conducted by means of rockets and space vehicles. In broad terms, it is concerned with pure scientific inquiry.

COSPAR expects to stimulate proposals for such experimentation, to evaluate these proposals, and to facilitate arrangements by which experimenters and launchers may combine or pool their efforts on mutually acceptable terms. Since

tracking and ground-based experimentation are closely related, efforts to provide for cooperation in tracking will be included. All of these activities can be of considerable value and utility to national operating agencies. (COSPAR expects that proposals for experiments by citizens of launching nations will be made first to their own national agencies.)

As during the IGY, the concepts, methods, objectives, and results of COSPAR-sponsored space research will be exchanged among the participating scientific communities by regularly arranged means of interchange.

COSPAR will have no launching facilities. The logistics will be contributed by national governments supporting their scientific communities as during the IGY—in their own interest and to the extent of their own interest. Such support has already been assured in the United States.

COSPAR will exercise no compulsion upon its members but will function purely as a scientific center to plan and encourage international cooperation, as did CSAGI, the international IGY coordinating committee. It will serve no regulatory function. It will, however, be deeply interested in the preservation of a climate and regulatory framework congenial to its interests and activities in space research.

Working groups on (*i*) scientific experiments, (*ii*) tracking and communication, and (*iii*) data and publications have already been established to carry out COSPAR's purposes and will shortly begin functioning.

COSPAR will also serve as a convenient device for gaining international endorsement of bilateral and multilateral projects in space research desired by operating agencies in this and other countries. Such a function was served most advantageously by CSAGI, the international coordinating committee in IGY.

The experience of the IGY and other related experiences of scientific everywhere suggests that these mechanisms of the scientific community, such as COSPAR, SCOR, SCAR, and the IGY itself, are particularly suitable for the conduct of international cooperative programs in basic sciences. Their character permits direct contact among scientists and allows consideration of program matters with maximum concentration upon their merits. By contrast, the discussion of scientific and technical matters through international organizations of a political composition, that is, on a government-to-government basis, is not nearly so satisfactory. Technical matters are confused with political considerations, often unrelated to the specific issues at hand, and there is considerable loss of flexibility, since every action represents a commitment for a government. Above all, negotiations avoid the formality of the political conference table where each country must speak through a designated representative. Emphasis is on advantages of agreement, not differences, and there is no room for propaganda issues. All participants enter the discussion and their views carry only the authority of knowledge.

I do not mean to suggest that international scientific programs, even when conducted through organizations of the scientific community, are without political implications. Appropriate regard to such implications must be exercised, and proper liaison and consultation with appropriate national agencies must be maintained for that purpose.

THE ACADEMY'S SPACE SCIENCE BOARD

The adhering body to ICSU in the United States is the National Academy of Sciences. The Academy was aware of ICSU's intention to establish a committee on space research. Further, the Academy recognized that it was as desirable on the national level as on the international to provide for the broadest possible participation of the scientific community in space research. Conversations were carried on with the heads of our national operating agencies, NASA and ARPA, as well as with the National Science Foundation, Dr. Killian's office, and the Department of State. Through these discussions it was agreed that the United States would support COSPAR, acting through the National Academy of Sciences. The upshot was that the Academy established the Space Science Board in August 1958, with two major purposes. The first was to aid in making available to the national space agencies in this country the capacities and participation of the American scientific community at large. The second objective was to represent American interests in COSPAR.

Dr. Bronk, the president of the Academy, honored me with appointment as Chairman of the Space Science Board. Fifteen distinguished scientists, representing a wide number of fields, were appointed as members: Dr. Harrison S. Brown, Dr. Leo Goldberg, Dr. H. Keffer Hartline, Dr. Donald F. Hornig, Dr.

W. A. Noyes, Jr., Dr. Richard W. Porter, Dr. Bruno B. Rossi, Mr. Alan H. Shapley, Dr. John A. Simpson, Dr. S. S. Stevens, Dr. Harold C. Urey, Dr. James A. Van Allen, Dr. O. G. Villard, Jr., Dr. Harry Wexler, and Dr. George P. Woollard. Dr. Hugh Odishaw has been appointed Executive Director of the Board.

The committee structure of the Space Science Board was designated with regard to the scientific areas to which consideration must be given in any program of space research. The Committees are:

Chemistry of Space and Exploration of Moon and Planets
Optical and Radio Astronomy
Future Vehicular Development
Immediate Problems
Space Projects
The Ionospheres of the Earth and Planets
Physics of Fields and Particles in Space
Future Engineering Developments beyond Available Facilities
Meteorological Aspects of Satellites
Psychological and Biological Research
Geodesy
International Relations

The membership of these Committees is listed in attachment B.

The International Relations Committee was established in particular to assure proper relationships with COSPAR. That Committee has recently been expanded to include liaison members from all interested government agencies, so that the National Academy's delegation to COSPAR may be responsibly informed as to the national space program and the opportunities which it presents for cooperative effort in collaboration with COSPAR.

To date, the Space Science Board has held four business meetings and three briefings and tours of inspection of national space facilities; one business meeting and one inspection tour were combined, so there have been a total of six meetings. The Board met June 27, July 19, and October 24–25, 1958, at the Rockefeller Institute in New York. On September 16–18, 1958, and October 17–18, 1958, the Board visited, respectively, the Army Ballistic Missile Agency at Huntsville, Ala., and the Air Force Ballistic Missile Division at Inglewood, Calif. From January 17–20, 1959, a combined Space Science Board business meeting, briefing and inspection tour was held at Capt Canaveral, Fla.

The Board's 12 Committees have met on 17 occasions to consider specific proposals for a recommended space research program. In addition to the 17 meetings noted above, 3 special ad hoc committees have met to consider relativisitic clock experiments, cosmic ray emulsion experiments in space, and interplanetary probes and space stations.

The Space Science Board moved very quickly to stimulate porposals for scientific experimentation that might be desirable for consideration in the immediate post-IGY period. Approximately 200 such proposals were received; they were quickly screened and passed to the appropriate agencies of government.

The results of the Board's deliberations were conveyed to NASA, NSF, and ARPA in November and December, 1958. Proposals included experiments in solar physics, magnetic fields, low-energy particle radiation, cosmic rays, and meteorology. The Board has been gratified by assurances that these recommendations have been of value to NASA. Further recommendations for projects in similar fields were prepared and transmitted to the operating agencies earlier this month. In all, about 100 proposals have been transmitted, together with some additional recommendations. These proposals are particularly significant for the following reason: Thus far we have perhaps had many more experiments available than we have had effective space in which to fly them; but unless our scientists work fast we shall soon have vehicle space begging for experiments to accupy it.

The problems which the Board feels require particular attention in space research are many. I might mention just two. We have not yet given adequate thought in this country to experiments designed to determine whether life exists on other planetary bodies and in what form. The Space Science Board has generated a number of informal meetings of qualified scientists to consider this problem as part of a continuing program. Closely related is the danger of contaminating other planets with organisms conveyed there by rockets, before we have adequately investigated those planets for indigenous life. A report of this danger will shortly be presented to COSPAR, at which time the Space Science Board hopes to advance a positive approach, avoiding the

dangers of contamination without at the same time unrealistically inhibiting space research. Perhaps it will be possible to so order experiments that the necessary investigations can be carried out before the greatest dangers of contamination are run. In any event, we should learn as soon as possible how to decontaminate the interiors of space vehicles.

Another problem of very great scientific and practical interest is to determine the extent and nature of the relationships between high atmosphere phenomena and the weather processes of the lower atmosphere. Experiments for this purpose should be given high priority.

To encourage fortification of scientists in the space program, the Space Science Board will shortly publish a space primer showing how scientists, universities and institutions can participate in space science. In addition, an outline of space science for the immediate future is now being prepared. Subsequently, the Board will examine the longer-range needs and implications of science in space.

CONCLUSION

In summary, I believe it may fairly be stated that the scientific community, both nationally and internationally, has moved very quickly to follow the lead of the IGY in space research. Efforts are underway to stimulate the interest of scientists everywhere in both national and international programs. Moreover, substantive contributions have already been made through the Space Science Board to the national space program, in representing to the Government the immediate needs of scientists in space research. These activities must continue on an ever-increasing scale if sufficient intellectual resources are to be made available to feed the rapid progress we expect in man's conquest of space.

Dr. BERKNER. Mr. Chairman, when Dr. Van Allen mentioned the fact that this scientific animal was one lying in the mud I was reminded of my last appearance before this committee when we were talking about radio telescopes.

Yesterday I was down to watch the first of these telescopes actually work.

West Virginia being what it is, I got so much mud on my feet that the colored boy on the sleeper last night took one look at my shoes and said, "Mister, I cannot do anything with those."

This is the kind of thing your committee gets us into.

Mr. THOMAS. What became of that $1.5 million we gave you to build a road? We were trying to help you avoid getting your shoes muddy.

Dr. BERKNER. That was only $60,000.

Mr. THOMAS. Go ahead.

Dr. BERKNER. Looking back at the International Geophysical Year, one feels a little like a scientist who has come in from outer space and discovered a new planet. There are so many things about this earth we discovered during the IGY that we did not realize before. A man thinks of the earth as a kind of a stable planet because his life is fairly short, but actually there are many things that vary. It is a very dynamic planet that is changing in many respects and we are learning in our lifetime about these changes.

When Dr. Shapley whistled, I was reminded of the remarks of the chairman at the hearings of 2 years ago when I described a whistler and then whistled—he remarked and I believe this can be found in the old record—he said, "This is the first time I have ever had anyone come in here and whistle for his money."

In a sense, Mr. Thomas, now that the IGY is over, it has been, as I think we all agree, a very outstanding success in making discoveries. It has occurred to me that the scientists ought to hold a hearing to which your committee should come. You ought to have a certain amount of pride in having backed this sort of thing. As a matter of

fact, in looking back at our satellite project, you will recall that it took a considerable amount of courage to back the kind of project never done before and which at that time——

Mr. THOMAS. And a considerable amount of genius on your part and all of your associates and Dr. Kaplan to organize this thing and make it work. It is nothing short of a miracle in my humble judgment, even to get them organized, 66 foreign countries.

Dr. BERKNER. This is the whole genius of the IGY. Everyone worked on this together. The administration worked on it, Congress, scientists, and the country. It really worked and the results are coming out rapidly and while there are great philosophical satisfactions, as you mentioned, I would be willing to stick my neck out and say that in 20 or 25 years the results of this will have brought back ten or one hundred times the money to the Treasury in terms of value of the knowledge to the future development of our society than was ever put into it.

Mr. THOMAS. You must have read this committee's last report.

Dr. BERKNER. I have read it but I would like to say this on my own.

Mr. THOMAS. We will adopt your remarks then.

Dr. BERKNER. I am really testifying this afternoon from the point of view of space activities.

As you know, I was a reporter for the International Geophysical Year in the field of rockets and satellites.

INFORMATION ON U.S.S.R. PROGRAM

I might say in response to an earlier question, and as a plug for some of our own work, that a book was published and part of the manual of the International Geophysical Year describes in considerable detail the Russian rockets and satellites that are carried on those rockets.

The second volume will be completed on the symposium held in Moscow last year and it contains a great deal of additional information on the Russian rockets, their experiments and on the results.

This will appear in print in a relatively short time and as rapidly as possible we are producing this data so they are generally available to everyone.

In the earlier book one can find pictures of the Russian rockets and details they have given us and how they are constructed and some of the ideas that are used in their launching.

There is little need to discuss further the achievements that have been made during the IGY but I would like to look ahead a bit to see where we are going in this field of rockets and satellites, which was really started on a very large scale as part of the IGY.

FUTURE INTERNATIONAL PROGRAM FOR SPACE RESEARCH

It became evident to the International Council of Scientific Unions that continued international cooperation in this field would be very desirable for a variety of reasons: One is, quite obviously, tracking stations have to be operated in many different countries; telemetry has to be done in different places; there are scientists abroad who have good ideas that should be incorporated in the experiments in rockets and satellites and as a consequence of all of these factors the International Council of Scientific Unions at its meeting here in Washington

last October 1 established an International Committee on Space Research to continue the collaboration in scientific research, using rockets and satellites.

This Committee had its first meeting in November, about November 13 of last year, and will have its next meeting in March, a little less than a month from now at The Hague. The purpose of the Committee is to continue the kind of operations in space that were carried out during the IGY, and in my formal testimony, which I would like to put in the record, is a considerable description of just how this Committee is organized to function and what the membership and purposes of the Committee are.

NAS SPACE SCIENCE BOARD

The National Academy, however, at an earlier time, because of its very close relations to the IGY—it was the sponsor of the IGY—decided rather early last year that there must be a continuation of the general scientific support of the space program and Dr. Bronk, who is president of the Academy, organized the Space Science Board of the National Academy to pick up the scientific responsibilities throughout the community and to focus them in the Academy through this Board. The Space Science Board has cooperated very closely with various agencies of Government, including the NASA, as soon as it was formed, the ARPA, Advanced Research Projects Agency of the Department of Defense, and the National Science Foundation, of course, which supports many of the early research projects that eventually will find their way into space.

Mr. THOMAS. Doctor, will you yield just a minute? This group here will have to go into great detail and take into consideration many, many details in arriving at the budget for that distinguished crowd. We will undertake that in some 2 or 3 weeks.

Maybe we had better have you and Dr. Bronk and some more members offer to advise us.

Dr. BERKNER. We would be delighted to help in any way we could, Mr. Chairman. What is happening now in the field of the Academy's work is, first of all, a very thorough study of what space technology and what space science will look like in the future, with particular reference to the scientific experiments that can be done to advance science in a very major sort of way.

FUTURE EXPERIMENTS

I might say that quite aside from the very interesting meteorological experiments that Dr. Reichelderfer mentioned or the experiments in astronomy that will be done from satellites in the future, one can look at some very fundamental experiments in science that can really be done in no other way. Let me just give you two examples.

GENERAL RELATIVITY

The first example is in the field of general relativity. You remember Einstein proposed the theory of special relativity and also a theory of general relativity. There is no doubt the theory of special relativity is correct because our cosmotron wouldn't run at Brook-

haven, if it wasn't, but the theory of general relativity is by no means proven. Observations were made about the early twenties on the effect of the Sun on Mercury, taking into account general relativity but these observations were only within the limits of experimental error and while it looked as though general relativity was probably true, it could not be proven from those experiments.

Subsequently, there was a tendency on the part of science to accept general relativity as probably correct until 2 years ago, when science was shaken thoroughly by the discovery that parity was not a general principle and indeed was not generally correct, and this was such a shaking discovery in science—you recall this led to the Nobel prize—that I think science is now prepared to question anything that is not really tested. There are a variety of ways in which the theory of general relativity can be tested, using space vehicles, one method, a clock in space with a clock on the earth, the clock in space being on a lower gravitational field, will probably be done in the next 2 years.

I emphasize this because this is one of the most fundamental things science can do in trying to find out the laws that govern our whole universe and our immediate environment.

GRAVITY

The second thing I would emphasize, and I say this without knowing how it is going to be done, but I am confident it will be, is a reexamination of the whole situation with respect to the character and nature of gravity. It is impossible to experiment with gravity when you are on the surface of the earth, because anything that happens with respect to gravity has to be unavoidably attributed to the environment which the earth provides us. In other words, we are in a big gravitational field that varies somewhat. There is nothing we can do about it. There are no experiments we can think of that can be done on the earth that tells us anything about gravity. When we get far out into space, we will be in a very low gravitational field and the whole matter of studying gravity takes on a new complex, and so, I cite these simply as two examples of the fact that the space activity that was started out of the discussions right here in the committee.

Mr. THOMAS. Suppose when we get up, we get a little platform out there 10 or 15 years from now and we measure gravity and we find out we are a little in error. What will we do about the error we discover?

Dr. BERKNER. I don't think we are looking for errors. We want to find out why gravity exists at all. Maybe if we find this out we can do something about it.

Mr. YATES. You have to find it out to put your platform up there.

Mr. BERKNER. Yes. When we get out into a very low gravitational field a whole new opportunity for experimental work comes up. If one finds out what gravity is, how it behaves, there are always possibilities you can do something about it.

WORK OF THE SPACE SCIENCE BOARD

Well, the Space Science Board is looking into this whole question of what kind of experiments are promising, and which are likely to be of the greatest value to scientists generally, and in doing this study, it is trying to do two things: One, to help the Federal Government in deciding the order and effectiveness of the experiments and secondly, to encourage the scientific community itself to get into the space work. After all, people have been doing other things, and if we are going to be strong in this field, in which we have already heard the Russians are strong, then some of our best scientists have to get into the act. So we are endeavoring to encourage them to get in. Finally, in a short time, perhaps within a few days, the Space Science Board will publish a space primer, which will aid scientists in getting into this work, so that we can broaden the base of the scientific activity underlying our space science program.

The Space Science Board will be the U.S. National Committee for the international work going on under the Committee on Space Research, which is the international committee, and it is through our work here in the United States that we will be represented on the Committee of Space Research in just the same way that Dr. Kaplan's Committee on the IGY represented the United States on the international body for IGY.

I believe this completes my testimony.

Mr. THOMAS. You have certainly made a wonderful statement and we thank you very much for it. You are always perfect.

IGC–1959

Dr. KAPLAN. Thank you very much, again, Mr. Thomas. In my opening remarks I tried to summarize the contents of my own testimony. I did not spend, as I feel particularly in terms of the testimony that has occurred, enough time on what has been called the International Geophysical Cooperation of 1959. Mr. Shapley, in his remarks, mentioned it in a little bit of detail.

The complete story of this extension of the IGY, if one wants to call it that, is on pages 7–14 of my testimony.

U.S.S.R. PROPOSAL TO EXTEND IGY

This includes, first, the history of how it came about. Last summer, before we went to Moscow, the Committee learned about the proposed agenda item to be introduced by the U.S.S.R. representatives there of a proposal to extend the IGY for another year, because of its great accomplishments, possibilities, et cetera.

As you know, before that time, we had intended, our plans were to end the IGY with the calendar year of 1958, go into the interdisciplinary area, the reduction of the data, and the research. In some special areas that have already been mentioned—Dr. Berkner mentioned the COSPAR and Dr. Revelle talked about the Special Committee on Oceanic Research—new organizations were to be

established. New international programs of considerable magnitude were, in fact, planned in these areas; and my own feelings, and possibly those of others, were that special committees would be set up for each of these special areas. This had been our intention, and an intention which was well known.

Based on conferences held here before we went to Moscow, in which I unfortunately did not take part because I was already on my way to Russia at that time, the position of supporting continued cooperation in geophysics, along the lines of IGY, was established with Foundation concurrence. This position we stated very clearly in Moscow; and finally there was the agreement for an IGC-1959. This was embodied in a resolution, described and formally adopted by the CSAGI, and I quote:

> That observational and data collecting activities in the geophysical and related sciences be conducted during 1959 on the same general plan as 1957–58 under the direction of CSAGI, or its successor, as far as practicable and at such level and in such fields as may be determined by each participating committee. The name "International Geophysical Cooperation 1959" is suggested for this period.

CSAGI ACTION

The General Assembly of the ICSU to which Dr. Berkner referred, endorsed this recommendation and established a new Committee, called the Special Committee for Inter-Union Cooperation in Geophysics (SCG) to succeed CSAGI, to provide cooperation in international programs in 1959. It was to this Committee that Dr. Shapley, who is a member—and I think Dr. Berkner is a member—referred.

Mr. THOMAS. Should the committee anticipate a budget estimate in regular form, deficiency or anything for this new organization?

Dr. KAPLAN. I can come to that very quickly. We have outlined the program in three parts, one which we call network activities, under which programs in, for example, meteorology, ionospheric physics, and geomagnetism will be continued. Dr. Reichelderfer has told us that support has been obtained for continuation in 1959 of five IGY upper air stations in Chile, Ecuador, and Peru. Ionospheric physics (vertical incidence soundings) will be continued by the National Bureau of Standards. Geomagnetism will be continued by the U.S. Coast and Geodetic Survey as will in its net of oceanic tide gage stations.

Under the second item, which requires no special moneys are programs already funded. Here are, first, the Antarctic, which has already been talked about, and second, Space Science, that Dr. Berkner mentioned.

The third category of our proposed IGC–1959 program is the one that requires immediate funding if we are to play our role in IGC–1959.

FISCAL REQUIREMENTS FOR SPECIAL PROJECT

I want to emphasize that term "immediate" because if we do not get it, it is going to be too late. Some of the items in this have already been mentioned. There is a list of some 30 to 40 projects in 12 fields carefully selected, many of them carrying the connotation "continuation" of certain things that have been going on in the IGY.

Mr. THOMAS. Has it been submitted to the Bureau of the Budget yet?

Dr. KAPLAN. No; it has not. The story of the budget background about this I think Mr. Odishaw can tell better than I can. I will call on him, with your permission.

Mr. THOMAS. What is the price tag?

Dr. KAPLAN. Such things as rocketry, meteorology, oceanography, seismology, the gravity surveys to which Dr. Woollard referred earlier, the use of the gravimeter.

The amount estimated for this, which includes world data center A having to receive more data from IGC-59, comes to approximately two and a half million.

Mr. THOMAS. This is the sum total of all?

Dr. KAPLAN. This is it. This is item 3, the special projects under the IGC-1959.

Mr. THOMAS. Is this contemplated to be a continuation of the National Science Board being the parent agency for budgetary purposes, or is this going to be a separate organization? Tell us about it, Dr. Odishaw.

Dr. ODISHAW. All I can say there is that the U.S. National Committee for the IGY has made certain recommendations that fall into those three categories.

Mr. THOMAS. Submitted to the Board and the Board in turn submits it to the Bureau of the Budget. What are the mechanics you follow?

Dr. ODISHAW. The procedure has been to submit these to Dr. Waterman.

Mr. THOMAS. That is the Board. Has it already been submitted to Dr. Waterman?

Dr. ODISHAW. Yes.

Dr. WATERMAN. Yes, sir. We have a list. It has been taken up with our Board.

Mr. THOMAS. Has your Board come to any conclusion on the matter?

Dr. WATERMAN. At the present time, Mr. Chairman, what we are doing is taking the IGY funds that have been appropriated for that purpose and hoping through cooperation with the National Committee to see that those projects are carried out as needed to extend the program for the limited time left in the IGY actual observations.

Mr. THOMAS. Maybe I am asking you a question that the committee should not ask you at this time. Have you completed your general planning.

Dr. WATERMAN. We have not completed the examination, but we have money available to cooperate with the National Committee in these recommendations.

Mr. YATES. You mean two and a half million dollars? You say you have money available. Do you mean $2.5 million?

Dr. WATERMAN. We have money available to do various things we are required to do. We are in the process of weighing all these things.

Mr. THOMAS. You are talking about money that is appropriated directly to the National Science Foundation and not to the IGY. You have no-year funds, of which you have quite a few.

Dr. WATERMAN. After all, this is research. There is a lot of research in the country.

Mr. THOMAS. Do not commingle your funds.

Gentlemen, are there any further questions?
Mr. YATES. Yes. I have a question.
Mr. THOMAS. Mr. Yates.

NATIONAL SCIENCE POLICY

Mr. YATES. I have been chasing Dr. Berkner a long time because I want to ask him about an article he wrote in the Atlantic entitled "Wanted—a National Science Policy." In that article, Dr. Berkner complimented the World War II Office of Scientific Research and Development in the same way Dr. Van Allen did, saying that we engaged in a great cooperative effort in World War II once the war was over, we lost our steam.

Dr. Berkner, I asked the others who were present in the NSF hearings for 1959, that is the members of the National Science Board who were present, about statements you had made. I would like to ask you the same question. The statement you made was this:

> On the whole, the American research approach has been unimaginative, controlled largely by fiscal agents of the Federal Government using methods and criteria which have been extraordinarily frustrating.

Now, as one member of a committee that wants to and tries to cooperate to the greatest extent possible with the scientific community in placing the United States in the forefront of world science, I find that statement a little frustrating. You talk about fiscal agents. I assume that you may have been referring to the legislative fiscal agents as well.

Can you tell us what you have in mind and what kind of a science policy the United States should be pursuing?

Dr. BERKNER. I would be glad to try to answer that, Mr. Yates.

I am sorry you weren't at the lecture that I gave jointly to the National Science Foundation and the American Association for the Advancement of Science this morning.

Mr. YATES. I was not invited; otherwise I would have been there.

Dr. BERKNER. There are some areas of science, of course, which are proceeding very well in this country and there are some other areas of science that are not at all proceeding well. One can cite the ones that are not proceeding well, such as the fields of meteorology and oceanography. I might also mention seismology, and I am naming these only from the earth sciences, with which I am closely related.

Mr. YATES. But this does not relate to science policy, does it?

Dr. BERKNER. Yes; it does. I would like to relate it. Specifically, science has to be supported by a variety of means. Some of science yields very well to support by individual projects in which professors at universities, graduate students are provided with small grants to investigate ideas which are within their realm of capability to investigate, but there are other problems in science that are much too large to be supported in this way because the individual can find no opportunity to do the work that he needs to do within the realm of small-project support. For example, I think Dr. Reichelderfer would agree that there are prolific clues to improving our understanding of meteorology, but that these clues generally lead to the understanding of meteorology on a global scale. It is perfectly clear that very little can be done by a small grant to a university professor if he has to look at meteorology as a global phenomenon. Conse-

quently, some of our support has to be given and organized so that the individual has opportunity to look at the global aspects of meteorology.

Precisely the same thing is true in the field of seismology. If one wants to look at the origin of an earth shock, or the character of the intervening earth that transmits it, it is necessary to have a large number of instruments, so coordinated that the study can be made, and it probably takes a computer on top of it, and it is quite beyond the capacity of one individual with a small grant to do anything about it.

Consequently, there has to be a kind of organized package approach to this job.

Mr. YATES. You mean internationally organized package approach?

Dr. BERKNER. In some cases international, but most certainly national mostly in these kind of problems. I can give an example. In the Antarctic, if you send out a traverse, it requires years of planning in advance to make that traverse effective. One wants a variety of kinds of scientific activity to go on in that traverse. If the grants are made independently, the traverse couldn't possibly be successful, because the grants would not relate to the specific circumstance in which the traverse is made.

Moreover, it may be that some science that should be done on that traverse would not stand up when weighed against some other scientific project at that moment, although as long as the traverse is being made, wisdom would dictate that that science should be carried on during the traverse. Consequently, you have to look at the whole matter as a package.

Let me say that I would not advocate that all science be supported this way. There is much need for support of science on an individual basis, but I would say that, in addition to that, one must be able to create the opportunity for individuals to carry on research, which is proportional to the size of the research problem at hand. Some of the most important things that we have to solve now, oceanography, meteorology, seismology—one can go on and make quite a long list—relate to packages which are beyond the abilities of an individual.

Mr. YATES. Is it beyond the capacity of the National Science Foundation to do this?

Dr. WATERMAN. We contract for this.

Dr. BERKNER. This is the difficulty.

Mr. YATES. The National Science Foundation cannot be a sole agency for carrying out a national scientific policy if this is true, is that correct?

Dr. BERKNER. It can and does in some instances. I point out to you one specific case it is supporting at the present time, the National Radio Astronomy Observatory, where you have the situation of the individual scientist having to have a very large tool in order to get on with the job at all. We discussed this with the testimony.

Mr. YATES. This is carrying on a facility that will be used as a national tool.

Dr. BERKNER. Exactly.

Mr. YATES. What about the IGY continuation? Can it really fit within National Science Foundation funds as such? Would it have to qualify as a part of its research program, or should it be a separate

part? This is the crux of the dispute, is it not? I gather the impression from what Dr. Waterman said, that NSF has funds within its budget now to carry on various programs, but not a single program known as the IGY.

FUNDING OF U.S. IGC–1959 PROGRAM

Dr. WATERMAN. If these research projects in the IGC compete favorably with the projects we get from other sources, there is no problem, but if it is a package deal such as happens in some of these cases, then this would probably call for special appropriations.

Mr. YATES. If this is true, do you have, as you indicated before, funds in the National Science Foundation to carry on a package project like IGY?

Dr. WATERMAN. No—not specifically for this purpose.

Mr. YATES. Your answer to that is "No"?

Dr. WATERMAN. That is what we have to study right now.

Mr. YATES. As I understand it, all the scientists who have come in here today have indicated that they would favor carrying on IGY as a package program; is that correct?

Dr. KAPLAN. As a uniform agreement. There is strong agreement on that in the USNC–IGY Executive Committee.

Mr. YATES. How does one do this in the absence of a budget request?

Dr. WATERMAN. That is what we are now studying.

Mr. YATES. Will there be time, when your study is completed, with which to obtain funds to carry on such a program?

Dr. WATERMAN. I wold certainly hope so. We are making every effort to go ahead.

Dr. KAPLAN. If I may break in, Mr. Yates, I must make a strong representation of the opinion of the Committee, my own opinion, and careful study, knowing what the other nations will do—one other nation in particular—I really do not think there is time. I think we literally have to abandon this phase of IGC–1959, unless we adopt the package as it is and do it immediately.

Mr. YATES. When are the funds required to be available? During fiscal year 1959 or during fiscal year 1960? In one case you need an appropriation via the supplemental bill; in the other you can get it in the regular budget.

Dr. KAPLAN. I would say both. We need funds to start. We need funds to continue.

Mr. YATES. When does the year end? When do you propose to spend the 2.5 million you talked about?

Dr. KAPLAN. During the calendar year.

Mr. YATES. Now you need part of the funds in the supplemental and you need part of the fiscal year 1960 funds.

Dr. KAPLAN. That is right.

Mr. YATES. There is no budget estimate in the supplemental that is now before the Congress, is there?

Dr. WATERMAN. No.

Mr. YATES. Then where are we? What will happen!

I would like to have a copy of your lecture this morning, Dr. Berkner.

Dr. BERKNER. I do not have a copy with me, sir.

Mr. YATES. It should go in the record. I understood you to say this explains your idea of what the national science policy should be.

Dr. BERKNER. Yes.

Mr. YATES. I should like to have it go in the record at this point.

Mr. THOMAS. Very well.

(The statement referred to follows:)

In the second year of the space age a radical change in American attitudes toward science and education has become noticeable. The Russian success, in a field where America should easily have led, has forced a reappraisal of American attitudes and actions—a reappraisal that is not yet completed.

Today I would ask, first, what new has happened since sputnik? Have we really devised and initiated actions designed to check the deterioration in our national scientific stature? The answer is "Yes," and we can cite some striking measures that have been undertaken.

Then, I shall inquire whether the measures to date are adequate. Here the answer is "No," and a number of examples of deficiencies will be noted.

Finally, I will inquire into the adequacy of certain aspects of our present Federal organization in science, and consider some alternative measures that seem imperative if serious deficiencies are to be corrected.

Let us turn first, then, to the positive side of the ledger—what have we done as a consequence of sputnik?

The appointment of the Science Adviser to the President, and the instatement of the President's Science Advisory Committee directly at White House level has been a major accomplishment. Certainly, this step has profoundly influenced all that has followed, for the needs of science, scientific research, and science education can now be understood and discussed at top governmental levels. Scientists finally have a definitive access to government. Although this stop is not a cure-all, it is certainly an immense step forward that makes consideration of corrective actions more likely.

Second, serious cuts in funds for science and technology made by the Department of Defense a little more than a year ago have been largely restored over the subsequent months. Few people ouside the graduate schools have realized the devastating effects of those so-called economy measures. Over the years since the war, the Department of Defense had increased its support of work under direction of the universities to about $300 million, of which some $30 million was for research involving graduate students. Having created this university dependence on Government, the Department of Defense, in issuing its orders to cut, appeared to be ignoring completely the consequences of such action on the growth of our scientific and engineering manpower. Certainly, sputnik saved us from the serious consequences that would otherwise have been inevitable.

Third, the National Science Foundation finally seems to be coming into its own. Established by the Congress in 1950, it struggled through its first few years with appropriations far below even its fixed ceiling of $15,000. When the ceiling was lifted by legislative action, the situation improved somewhat. Until the current year, however, its peak appropriation had been $40 million. And of this amount, less than half went for the actual support of science; the remainder went for science education, fellowships, and other activities specified by law. Yet Vannevar Bush, in his report to the President, "Science, the Endless Frontier," had, as early as 1944, visualized the Foundation as growing to a level of $125 million in 5 years. As a direct result of sputnik, its 1959 appropriations total $130 million, certainly a radical recognition of the neglected importance of science and technology. Moreover, in response to recommendations by the National Science Foundation, Congress has authorized all departments to utilize the grants as an instrument for research support.

Fourth, the 6-year $1 billion student loan bill was passed. For the first time the government has recognized the gifted student as an asset worth capitalizing. Now the way is clear for all gifted students to realize, more nearly, their optimum capabilities. This is a large entry on the positive side of the ledger.

Fifth, the National Aeronautic and Space Administration was created under civilian auspices and under law with which few would seriously quarrel. Moreover, substantial appropriations and transfers of funds appear to initiate this agency on an impressive scale of a quarter billion. This bids well for the future of our space research, and a whole variety of related scientific activities.

Sixth, substantial reorganization of our military research activities has led to direction of research effort into more useful and urgent channels. The creation of the Advanced Research Projects Agency with executive authority is a major step forward. Likewise, the reorganization of the Department of Defense itself is influencing our military effectiveness in a way that will soon be felt. The reorganization seems certain to lead to a more intelligent treatment of some of our most urgent and difficult defense problems.

Seventh, I would mention appropriations made for many facilities that had been knocked out of the budget, to be restored in the shadow of sputnik. The appropriation for our first large precision radio telescope is a case in point. Likewise, research facilities in the field of atomic energy, restored by the Congress over the head of the Executive branch, will help to repair the deficiencies that had been for 5 years accumulating in this field, though the facilities in the American research establishment generally still remain grossly inadequate.

Eighth, the post of the Science Advisor to the Secretary of State was filled again after a lapse of nearly 5 years, and a plan to restaff the offices of the science attaché abroad was accepted and funded.

Ninth, the Congress had taken action to make the Federal service more attractive to scientific and technical personnel. Departments can now grant leaves-with-pay for advanced studies similar to sabbatical leaves granted by the universities. Other attractions, such as payment of moving expenses can now be granted as has been customary in nongovernmental employment. In adopting these measures, the Congress has shown realization of the need for nurturing first-rate men of scientific and technical skills in Government.

Likewise, the House of Representatives has created a Standing Committee on Science and Astronautics to review the needs and activities of such agencies as the NASA, the National Bureau of Standards, the National Science Foundation, and the Smithsonian Institution. For the first time science has been given full stature in the deliberations of a House of Congress. The corresponding new standing committee in the Senate recognizes only astronautics, and an extension of its responsibilities to science must be awaited.

Finally, people themselves, through committees and school boards, have undertaken revision of the curriculums for secondary education. The recent books of Conant, Rickover, and others provide guides and stimulate discussion. The pipe electives are being reconsidered, and math and science are coming back into the high school on a substantial scale. Citizens are reexamining the responsibilities involved in education. Likewise, the universities, with the National Science Foundation, are helping to bring textbook and teaching methods up to date. The MIT work on physics teaching and the Yale revision of the mathematics curriculum in the high schools are having widespread impact. Communities are reconsidering tax structures to increase the attraction to the teaching profession. The attitude that high schools should be institutions that teach the disciplines of thought and learning, rather than kindergartens for play, is again becoming respectable.

I submit to you that this is an impressive list of accomplishments. It certainly does not justify the oft-heard comment that "nothing has happened since sputnik." Quite to the contrary, really major measures have been initiated in a little more than a year through genuine effort of the Executive branch of our Government, the Congress, and the people. I must add that I believe that a very great influence in this change has been the Science Advisor to the President, Dr. James R. Killian, and the President's Science Advisory Committee. For the first time, the President and his administration have had direct access to knowledge of the interaction of science on government, an interaction that now influences government more than any other single factor.

But impressive as this progress has been, it is far from meeting the entire intellectual challenge of our time. The drastic nature of the remedies serves to emphasize the depth of our intellectual deterioration as an advanced nation in the pre-sputnik days.

The sputnik has demonstrated that we are engaged in more than a military contest; it is a total contest in which intellectual leadership plays a major role. The contest requires that the victor demonstrate the ability of his system to provide opportunity to accomplish easily those things that men want and admire. Promise of individual freedom and dignity, and mere material welfare, are not enough. To these essential ingredients, peoples expect of a nation that would be great, the added opportunities to challenge the frontiers of mind and nature—opportunities that man has treasured in his rise to civilization. The world's recognition of the challenge of space is but a symbol of this need. We can

now see more clearly that national superiority comes from positive measures of sound and widespread education, adequate laboratories, a spirit of daring to embark or new and challenging ventures—in short, all those measures that together spell the intellectual stature that emerges from creative opportunity to our citizens. In this perspective, we can see that the actions taken in the past few months have been interim and urgent measures to check our fall. They are by no means the sole elements of a complete policy to insure our leadership in the future. But before we discuss some of the major elements of such a policy, we would benefit by looking at some remaining deficiencies that may be used as guides to future action. I shall select some examples from the earth sciences with which I am most familiar.

We have heard a great deal of talk in recent years about weather control. Certainly, if weather modification is possible on a large scale, it would have most profound social, military, and economic consequences. A nation that developed a capability in this field would control moreover a most powerful potentiality. One would suppose in the face of this potential, that, as a matter of minimum commonsense, we should hasten to exhaust every promising avenue of research on such a problem. Nothing could be further from the fact. Two high level committees have studied the matter, one established by the National Academy of Sciences, and the other composed of the heads of the 14 American departments of meteorology offering graduate degrees in the subject. Both committees have reported, and their reports are in substantial agreement. What is urgently needed to supplement university effort is a major laboratory to provide facilities to attack the meteorological problem on a global scale—large and complex facilities that would extend the opportunity already available to university faculties. The laboratory should provide a giant computer capable of solving problems faster than nature solves them in the atmosphere, a squadron of specially instrumented aircraft to range into areas where special phenomena such as hurricanes, tornadoes, and the global circulation all can be observed and measured, rain towers to observe the physics of rain formation, wind tunnels to study atmospheric circulation, and laboratories for instrumentation of satellites and analysis of their data. Such a laboratory would cost about $15 million a year for operations. Yet our meteorological research sputters along on $3 million a year, working on insignificant problems while competent scientists sit on their hands awaiting facilities adequate to attack the really significant problems at hand. All that happens is sympathetic talk.

This is in the face of the fact that the petroleum industry indicates that $100 million annually would be saved if the accuracy of seasonal forecasting could be improved at 10 percent, since they would know where to ship their fuel. Even small advances in meteorological knowledge will yield billions to transportation, agriculture, and business. Quite aside from national military and social potentials that can be acquired from meteorological progress, the tax from those billions might well bail out some part of our present Federal deficit.

The same story can be told for oceanography. The oceans cover three-quarters of the earth's surface. Untold riches are doubtless contained in them and covered by them. During the IGY explorations, a submerged continent was explored from Tahiti almost to South America. That a whole continent of this kind should remain unexamined until this day is an indictment of our imagination and initiative. Reason dictates that the potential resources of the oceans should be explored and studied by every means. The Soviet Union now has 22 oceanographic vessels, led by the superbly fitted *Ob* of more than 12,000 tons. Contrast this with the half dozen yachts of our three or four half-starved oceanographic institutions.

As a third example, the means for thorough survey of geological resources and continental structure in depth are at hand. The Soviet is reported to be coring its continental strata at the rate of 200 deep holes each year. With such coring and simultaneous survey of geomagnetism, rock magnetism, gravity, natural and artificial seismology, geochemistry, radio chemistry, geochronology, and other available geophysical tools, it is reasonable to expect that with the supplementary activities of our oil industry, we could map our continent in three dimensions and assess our continental resources in a reasonable length of time. In the face of such a program, the meagerly supported efforts of our competent Geological Survey seem pitiful.

As a further example, one might mention seismology. This powerful phenomena provides not only the means of characterizing the nature and origin of earth shocks, but also supplies the major tool for exploring the earth's interior. With a piddling half million dollars a year, seismology has been unable

to grasp the opportunities that science could provide to it. Detailed knowledge of transformation of earth shock energy into waves, of phase equalization for intervening wave distortion, of methods of noise reduction, and of instrumentation designed in light of current techniques of electronics, remain but a gleam in the seismologist's eye. Now that such knowledge is urgently needed for our Geneva negotiations, we can only despair our ignorance, and the complacency that has perpetuated it.

One could go on to mention the deficiencies in our antarctic program where we have fallen far behind the Russians. Yet to the world, the Antarctic represents the last great geographic frontier whose scientific exploration remains a symbol of skill and foresight, of courage and endurance that characterizes a nation that would lead.

Scientific deficiencies such as these have one common characteristic. They require integrated planning and support for the science on the scale of the problems concerned. They have not yielded, and will not yield to support through a variety of independent and disconnected research projects on a small scale. Global meteorology can be understood only where studied on a global scale. The earthquake phenomena emergent from an earth shock require a chain of intimately interconnected instrumentation. Oceanography requires real ships, not yachts. A critical Antarctic traverse embraces many sciences and requires years of intimate planning. Scientific problems such as these require a kind of package support such as that demonstrated during the IGY.

Do not misunderstand that I advocate this form of support for all science. The individual project is ideal for many researchers. But in other fields of science there can be no opportunity for the individual unless the problems can be organized in an integrated package on an adequate scale. The successes of the great nuclear laboratories, sponsored by the AEC with their specialized and expensive nuclear tools, have been made possible by offering to the individual opportunity to carry on his research on the scale required.

But there is now no adequate organizational machinery in government to initiate or even to conceive of corrective measures for such obvious deficiencies as I have described. Such little oceanography as the Government does is split between the Hydrographic Office in the Navy and the Coast and Geodetic Survey in the Department of Commerce, where both agencies are effectively buried and regarded only for their nuisance value. The research support that is available for oceanographic activities from the Office of Naval Research and the National Science Foundation is subdivided into minute and unrelated projects. The Weather Bureau is lost in Commerce, and incidentally is separated from the ground-water half of the meteorological job because this is a function of the Geological Survey over in the Department of Interior. The Survey is likewise thoroughly buried under Interior's major interests in grazing, Indians, and territorial affairs. And so on through the list.

What, then, must be done? To analyze this problem, I would tentatively divide scientific activities in Government into three parts.

First is the science and scientific research that is the integral part of the program and objectives of certain Government departments and agencies. Such research is directly related to the mission of the departments and hence essential to their growth and evolution. Thus, the Department of Defense must have its supporting research for defense, and must further sponsor pure research so that it partakes of the reviving blood that science can provide it. To cut off the Department of Defense from access to the ideas that renew its vitality would be to damage our defense irrevocably. Likewise, the very lifeblood of the Department of Agriculture is scientific research in agriculture, biochemistry, and plant and animal biology, soil chemistry, and so on. Similarly in many departments, one finds activities in scientific research, conducted or sponsored by the department concerned, that are imperative for its intelligent and healthy growth.

The second major government scientific activity is research support. The Government supports a variety of scientific programs in many fields for the sole reason that such support helps to maintain the vitality of American science and technology itself. These are primarily the programs of grants and contracts of the National Science Foundation and the Department of Health, Education, and Welfare. They are frequently described as extramural programs of government, because their purpose is to help assure the continuation of free, uncommitted research in colleges, universities, and research institutions. These agencies support graduate students and individual pure researchers of professors. They contract for basic laboratory facilities that are necessary to a balanced American scientific activity. These agencies are not operating agencies in the

usual sense but rather have certain broad responsibilities with respect to the general welfare, including not only the encouragement of scientific research but the support of science education to the extent needed to keep America intellectually strong.

The third Federal scientific function is represented by those Federal services that cut across State boundaries and departmental interests and must, therefore, be performed by the Federal Government. There are a variety of such agencies that must provide very general technical services based on science that have no special relation to any single department of government, but are applicable to all departments, and to the country and to its business as a whole. As examples, among the agencies performing such services are the Weather Bureau, National Bureau of Standards, NBS Central Radio Propagation Laboratory, Coast and Geodetic Survey, Hydrographic Office, Geological Survey, Office of Scientific and Technical Information, Antarctic Offices of the Navy Department and of the NSF, Fish and Wildlife Service, and Naval Observatory.

These agencies provide those technical and scientific services that are the normal functions of government with respect to their citizens everywhere. They have no real organic relation to the departments with which they are individually associated, but find themselves assigned to one department or another largely through historical accident.

Let me summarize, then, the three parts into which I have divided Federal responsibility for science for purposes of this analysis.

1. The organic research activities of the departments that are integral and vital to the achievement of department objectives.

2. External Federal support of scientific research and education, conducted by nongovernmental organizations, universities, and laboratories, and unrelated to any direct organic responsibility of the supporting agency.

3. Governmental scientific and technical services, not principally involved in existing department objectives or strongly related in the organic sense to the functions of a single Federal department, but of the utmost importance to the Government and people as a whole.

This third responsibility is not now well discharged by Government, nor can it be, for a number of obvious reasons:

1. Since the agencies concerned do not vitally participate in the organic objectives of the departments concerned, they are "stepchildren" of considerable nuisance value to their individual departments.

2. The organizational division of interrelated scientific responsibilities among a variety of departments prevents the close collaboration that is imperative to the success of these services on matters of overlapping scientific and technical interest.

3. These agencies are at a vital disadvantage in obtaining budget support in competition with other bureaus more closely related to individual departmental objectives.

4. Since these agencies are minor departmental responsibilities, departmental heads have little knowledge of their real importance. Therefore, appeals for corrective action are not adequately understood or interpreted by departmental administrators.

The present organization of these vital activities has grown haphazardly over the past century. The time has come when organizational change is imperative.

I submit, therefore, that a new Federal Department of Science and Technology should be organized to bring the agencies of this third category together, with the objective of adequately developing the broad scientific and technical services of Government to meet the needs of today.

Such a Department might well include the following Divisions, among others:

1. Division of Physical Sciences and Standards.
2. Division of Oceanography.
3. Division of Meteorology, Climatology, and Water Resources.
4. Division of Continental Structure and Resources.
5. Office of Scientific and Technical Information.
6. Government Map Service.
7. Office of Time, Geodesy, and Astronomy.
8. Division of Continental Fish, Wildlife, and perhaps Conservation.
9. Division of Radio and Outer Atmospheric Research.
10. Office of Polar Activities.

The creation of such a Department would centralize Government responsibility for vital scientific functions that are now performed most inadequately in light of current needs of science and technology. It would bring together

closely related scientific responsibilities so that their natural relations could be exploited. Above all, it would provide the means for extending our leadership to scientific areas where we are now surpassed by other nations.

In advocating such a Department, I do not propose that it should try to set up Government laboratories to do the job at hand. This would defeat the very objectives of broadening the base of American science and providing opportunity to men of great skill wherever they may be. Rather, the Department should be a focus for the now neglected responsibilities in American science. In sponsoring scientific research, a Department of Science and Technology might well emulate the successful pattern of the Atomic Energy Commission in contracting to sponsor national laboratories or institutes in fields of meteorology, theoretical geophysics, polar research, and the like. Certainly, I would not preclude Government operation and expansion of such essential agencies as the National Bureau of Standards and the Naval Observatory. But, wherever possible, research facilities should be organized as a supplement to university and institutional activities, and easily accessible to their faculties.

You will ask why I have not included the National Science Foundation in such a proposed Department of Science and Technology. I believe that the objectives of the National Science Foundation are radically different from those of a Department of Science and Technology. Such a Department is designed to provide Government services in science and technology that are essential and must be provided on a nationwide basis. It must be closely related to operations at every turn. Its research activities are focused by those responsibilities. On the other hand, since the National Science Foundation functions solely with respect to extramural research, it is and should continue to be nonoperational. Its funds for grants and contracts should not be in competition with funds for internal Government responsibilities.

Likewise, I would not disturb the Department of Health, Education, and Welfare, which is now functioning successfully in the field of the life sciences. Although the National Astronautics and Space Agency and the Atomic Energy Commission are operating agencies in the same sense as the agencies in category 3, their size and specialized functions are such as to justify their independence. It would seem unwise to upset their successful operations for the doubtful advantage of operational symmetry. If combined into a new department, these two agencies would bury the very functions that the new Department should be designed to expand and develop. The purpose of the new Department should be to correct deficiencies, and not simply to engage in organizational exercises.

The most impelling argument that has been advanced against such reorganization of science in Government is that Congress is in no mood to stop with the kind of measures that I have proposed. There is real fear that in organizing a Department of Science and Technology, Congress would end up by dumping all the scientific activity of the departments and agencies into such a Department. An indiscriminate lumping together of all categories of Government activity in science would, of course, be little short of catastrophic. The damage so done would doubtless outweigh, by far, the advantages to be acquired. Because of this very fear, I believe, scientists generally have not advocated, or have even opposed the creation of a Department of Science and Technology.

Consequently, any initiative for corrective action should originate in the executive branch of our Government, where a carefully prepared and well-reasoned plan can be presented to the Congress. Failure of the executive branch to review broad deficiencies in Federal scientific and technological activity has arisen from lack, until recently, of any workable mechanism for examining and formulating technological and scientific policy at the top governmental level. Of course, such a charge was assigned by the Congress to the National Science Foundation. But, from my earlier analysis of Government responsibilities in science, it is readily seen that, organizationally, it is quite impossible for the Foundation to assume or to discharge this responsibility successfully. Since the Foundation discharges one of the three coequal functions of Federal science and technology, it cannot coordinate all three without endangering that function for which it is principally responsible.

For this reason, the position of the President's Science Adviser, and the Science Advisory Committee, assumes a major role in examination and formulation of overall broad policy for Federal science and technology. I visualize their duties along these lines:

1. To assess the impact of science on Government in military, economic, and social aspects.

2. To evaluate the relative balance of the U.S. program of science and research, to insure adequate support for the whole range of opportunity for scientific research.

3. To be especially sensitive to new potentialities for scientific research and development, and to find means, and to recommend support for new areas of activity.

4. To review adequacy of support for reconstruction and extension of facilities for scientific research to keep America's research plant up to date. The objective should be the creation of a plant capable of investigation of clues that nature provides to the full extent of the tools that can be provided by the state of our technology. (Our research plant is now seriously obsolescent.)

5. To review constantly the character of opportunity and administration of scientists and engineers within Government, looking to improvement of Government personnel practices with respect to such men.

6. To ensure suitable and adequate Federal practices in support of scientific information.

7. To monitor Federal policies on international collaboration in science.

8. To review, from time to time, the effectiveness of broad Federal policies with respect to the general health of scientific research.

In these tasks the President's Science Advisory Committee might well lean heavily on the National Academy of Sciences. The Academy is representative of our most skilled scientific workers. In its statutory function of advising Government, the Academy should be especially valuable in assisting the committee in advising on explicit questions that the committee can properly ask it.

But, of course, neither the committee nor the Academy has the facilities for the detailed planning and preparation of data that are prerequisite to discharge of their policy responsibilities. Moreover, there are subfunctions of policy-planning that are intimately associated with departmental functions which can never be carried adequately by any external committee. Consequently, the new Federal Research Council at the level of departmental secretaries, or at least Assistant Secretaries, for Research and Development and chaired by the President's Science Adviser, assumes a major role in policy planning.

With the President's Science Advisory Committee for the broad policy function and with the Federal Research Council for policy planning, the President's Science Adviser should find adequate means of formulating both broad and detailed policy. These are the policy tools needed by the executive branch to plan a Department of Science and Technology and to guide it through congressional debate in suitable form. I believe that with these tools, the Nation can safely face the corrective action required by the present grave deficiencies in Federal science and technology through organization of a Department of Science and Technology, without danger of creating a governmental monstrosity that would wreck the direction of Federal scientific effort. We can now regroup related Federal responsibilities in science and technology from haphazard into workable form.

To achieve these ends demands a sober and challenging measure of responsibility at every level of social and political action.

Dr. KAPLAN. Mr. Chairman, I would like to thank you on behalf of our committee——

Mr. THOMAS. Doctor, we should thank you.

Dr. KAPLAN. Looking back over the long years of preparation and the carrying out of the IGY, I can honestly say some of the more pleasant moments have been spent right here.

Mr. THOMAS. You are wonderful. That pleases us greatly. However, you are not through with us. We will see a lot of this crowd.

Dr. KAPLAN. Call us and we will come.

Mr. THOMAS. I thank you folks and good luck to all of you.

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